

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

U. S. DEPARTMENT OF AGRICULTURE.

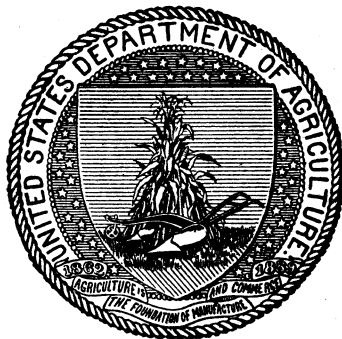
FARMERS' BULLETIN 408.

SCHOOL EXERCISES IN PLANT
PRODUCTION.

BY

DICK J. CROSBY,

*Specialist in Agricultural Education,
Office of Experiment Stations.*



WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., April 30, 1910.

SIR: Three years ago the Department issued as Bulletin No. 186, Office of Experiment Stations, a publication entitled "Exercises in Elementary Agriculture—Plant Production." The demand for this bulletin has been large and continuous, and notwithstanding the fact that four editions aggregating 22,000 copies have been issued the supply is now exhausted. The bulletin was prepared primarily for the use of public-school teachers, and since popular interest in the teaching of agriculture in the schools is growing rapidly, it now seems wise to reissue the exercises in the Farmers' Bulletin series. With this aim in view I have had Parts 1 and 2 of Bulletin 186, dealing with the plant and its environment, revised for publication as a Farmers' Bulletin on "School Exercises in Plant Production." Part 3, of Bulletin 186, "Lessons on Corn," will be revised and combined with Circular 96 of this Office, "How to Test Seed Corn in Schools," for publication as a Farmers' Bulletin on "School Lessons on Corn."

Respectfully,

A. C. TRUE,
Director.

HON. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page
Purpose of the bulletin.....	7
Scope of the bulletin.....	8
Materials for laboratory exercises.....	8
General plan of laboratory exercises.....	10
Exercises in plant production.....	12
Part 1.—The plant.....	12
Exercise 1.—To show that plants absorb moisture from the soil.....	12
Exercise 2.—How roots absorb moisture.....	13
Exercise 3.—To show that plants get food from the soil.....	15
Exercise 4.—To show that plants give off moisture.....	16
Exercise 5.—To show the rise of water in plants.....	16
Exercise 6.—Circulation of water in plants.....	16
Exercise 7.—To show that part of the moisture absorbed by the roots of plants is retained in the plant.....	17
Exercise 8.—To show that plants get food from the air.....	17
Exercise 9.—How plants grow.....	18
Propagation.....	19
Exercise 10.—Spores.....	19
Exercise 11.—Seeds—germination test.....	20
Exercise 12.—To make a balance.....	21
Exercise 13.—Seeds—purity test.....	23
Exercise 14.—Development of young plants from seeds.....	25
Exercise 15.—To show that young plants get food from seeds.....	26
Exercise 16.—Pollination.....	26
Exercise 17.—Layering.....	27
Facilities for rooting cuttings.....	29
Exercise 18.—To make soft cuttings.....	30
Exercise 19.—To make hard cuttings.....	30
Exercise 20.—To make grafting wax.....	31
Exercise 21.—Cleft grafting.....	32
Exercise 22.—Whip grafting.....	33
Exercise 23.—Budding.....	34
Part 2.—The environment of the plant.....	36
Exercise 24.—Conditions essential to plant growth—light.....	36
Exercise 25.—Conditions essential to plant growth—heat.....	36
Exercise 26.—Conditions essential to plant growth—moisture.....	37
Exercise 27.—Conditions essential to plant growth—air.....	37
Exercise 28.—Soil collection.....	38
Exercise 29.—Classification of soils.....	38
Exercise 30.—Light and heavy soils.....	39
Exercise 31.—Porosity—the capacity of soils to take in rainfall.....	39
Exercise 32.—Air in soils.....	40

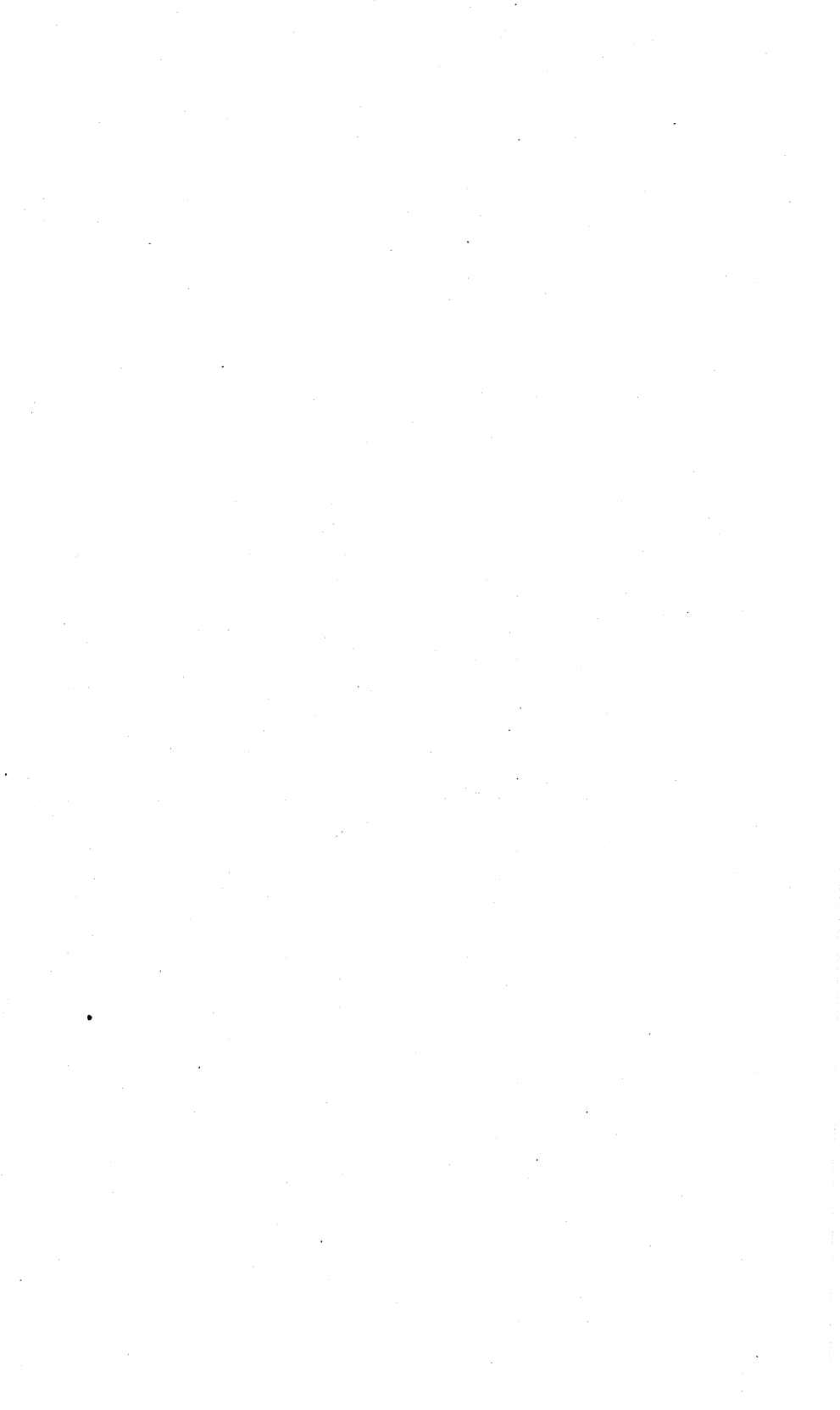
Exercises in plant production—Continued.

Part 2.—The environment of the plant—Continued.

	Page.
Exercise 33.—Capillarity—the power of soils to take up moisture from below.....	40
Exercise 34.—Puddling.....	41
Exercise 35.—The effect of lime on clay soils.....	41
Exercise 36.—Action of frost on soils.....	42
Exercise 37.—Temperature of soils as affected by color.....	42
Exercise 38.—Temperature as affected by moisture.....	43
Exercise 39.—Temperature of soils as affected by inclination of the surface or exposure to the sun.....	43
Exercise 40.—Free moisture in soils.....	43
Exercise 41.—Capillary moisture in soils.....	44
Exercise 42.—Hygroscopic moisture in soils.....	44
Exercise 43.—The influence of tillage and mulches on the retention of moisture in soils.....	45
Exercise 44.—To show the effect of plowing down manures and clods.	45
Exercise 45.—Influence of drainage upon plant growth.....	45
Exercise 46.—Effect of manures on plant growth.....	46
Helps for teachers.....	47

ILLUSTRATIONS.

	Page.
FIG. 1. An alcohol lamp made from a tin box.....	9
2. Wash bottle.....	10
3. A homemade garden line.....	10
4. A stamen.....	11
5. A pistil.....	11
6. Vertical section of a tomato blossom.....	11
7. To show that plants absorb moisture from the soil.....	13
8. To show osmosis.....	14
9. Osmosis shown with bladder membrane.....	14
10. To show that plants give off a part of the moisture absorbed from the soil.....	16
11. To show where roots increase in length.....	18
12. Seed-testing device.....	20
13. A simple balance.....	21
14. A serviceable tripod magnifying glass and a convenient mount for preserving seeds for study.....	24
15. Device showing proper depth to plant seeds.....	25
16. To show the best depths at which to plant corn.....	26
17. Plant food in seeds.....	26
18. Tomato blossom ready to pollinate.....	27
19. Tip layering.....	28
20. Vine layering.....	28
21. Mound layering.....	29
22. Frame for rooting cuttings.....	29
23. Leaf cutting—part of leaf.....	30
24. Leaf cutting—whole leaf.....	30
25. Stem cutting or “slip” of Coleus.....	31
26. Cutting set in trench.....	31
27. Cuttings: <i>a</i> , Simple cutting; <i>b</i> , heel cutting; <i>c</i> , mallet cutting; <i>d</i> , single-eye cutting.....	31
28. Grafting tool.....	32
29. Cleft grafting: <i>a</i> , Scion; <i>b</i> , scions inserted in cleft.....	32
30. Cross section of stock and scion.....	33
31. Whip grafting: <i>a</i> , The stock; <i>b</i> , the scion; <i>c</i> , stock and scion united... ..	33
32. A bud stick.....	34
33. Cutting the bud.....	34
34. Budding: Preparing the stock.....	34
35. Budding: <i>a</i> , Inserting the bud; <i>b</i> , tying; <i>c</i> , cutting off the top.....	35
36. Method of demonstrating the effect of too much water in soil.....	37
37. Arrangement for showing the effect of the exclusion of air on plant growth.....	37
38. Apparatus to test the capacity of soils to take in rainfall.....	39
39. Apparatus to test the power of soils to take up moisture from below... ..	41



SCHOOL EXERCISES IN PLANT PRODUCTION.

PURPOSE OF THE BULLETIN.

This bulletin supersedes a similar bulletin of the Office of Experiment Stations.^a It is intended as a laboratory guide or manual for the use of teachers and not as a text-book to be studied by the pupils. It is expected that the pupils will use a text-book on agriculture and that teachers will provide themselves with text-books and other helps as suggested in the section on "Helps for Teachers." They should also prepare themselves in advance on each lesson by working out the necessary exercises and familiarizing themselves with all details of the work. In this way they will learn what difficulties are likely to arise and what details of the less complicated exercises can safely be intrusted to the older pupils in the class in agriculture, thus saving time for themselves and increasing the value of the exercises to the pupils.

While success in this work will depend largely upon the personal influence and work of the teacher, there is nevertheless a duty incumbent upon school officers to improve the physical and material equipment of the schools. The very lowest requirements that could be considered adequate for carrying through these exercises are warm, light, well-ventilated schoolrooms—warm enough to protect tender growing plants from cold at all times.

While many of the exercises could be performed in any sort of room, or even out of doors, the series can not be followed out in the order given unless provision is made for growing plants in the schoolroom. And it is a matter of some importance that the exercises be taken up in the order given, so that each step may lead naturally and logically to the next. In the earlier nature-study work of the grades, formality, order, and the other accompaniments of science are kept in the background, so as to reduce to the lowest terms the embarrassment of getting acquainted with the "common natural objects and processes which appeal to human interest directly." But now that the pupils are to take up the more formal study of elementary agriculture, they should proceed in a more orderly way

^a U. S. Department of Agriculture, Office of Experiment Stations Bul. 186, Exercises in Elementary Agriculture.—Plant Production. This bulletin is no longer available for distribution from this Department, but can be procured for 10 cents from the Superintendent of Documents, Washington, D. C.

and be led to feel that in nature things do not "just happen," but follow inexorable laws of cause and effect. It is for the purpose of illustrating the application of some of these laws that these exercises have been brought together.

SCOPE OF THE BULLETIN.

The course in agriculture for the rural common schools, as outlined by the committee on instruction in agriculture in its ninth report to the Association of American Agricultural Colleges and Experiment Stations,^a was designed to extend over two years, the seventh and eighth years in schools having eight grades. The first year was to be given up to a study of plant production, and the second year to animal production and some matters concerning dairying, farm mechanics, and farm accounts. The experiments thus far tried in teaching agriculture in the elementary schools have been directed mainly along the line of plant production; hence there is much more material in teachable form on this phase of agriculture than on any other phase. On this account, and for the further reason that a bulletin dealing with the whole subject of elementary agriculture would be so large as to preclude its wide distribution, it has been decided to limit this bulletin to exercises illustrating some of the more important principles of plant production, leaving to subsequent bulletins the application of these principles to particular crops.

MATERIALS FOR LABORATORY EXERCISES.

The rural elementary school is fortunately located in the midst of a bountiful supply of illustrative material for the outdoor study of agricultural subjects. There are birds, trees, flowers, growing crops, and other nature-study material all around it; land for school and home gardens is readily available, and well-managed farms with field crops, live stock, farm machinery, and good buildings are usually near at hand. Such material as this should be utilized to the fullest extent. Every farm and home in the district should contribute to the agricultural work of the school, and the farmers themselves should be asked to talk to the pupils and give them the benefit of their experiences. In this way "training in the elements of failure and success" can be effectively given and the patrons of the school can be made to realize that the elements which contribute to intellectual training and culture are not all confined within the covers of text-books.

But while it will be best to take the pupils out of doors for much of their practice work, some of the principles of agriculture do not lend

^a United States Department of Agriculture, Office of Experiment Stations Circ. 60, The Teaching of Agriculture in the Rural Common Schools, and Bul. 164, Proceedings of the Nineteenth Annual Convention of the Association of American Agricultural Colleges and Experiment Stations, 1905

themselves readily to illustration in this manner. There is need of some laboratory work which can best be performed indoors with specially prepared apparatus. The material for this apparatus is inexpensive, and much of it could be provided by the pupils. Two dozen empty tomato cans, three or four lard pails, a few baking-powder cans and covers, a lot of empty bottles and corks of different sizes, a few small wooden boxes, some empty packing boxes, a collection of typical soils (clay, sand, loam, and muck or peat), and a few seeds of garden and farm crops, will enable the teacher and pupils without expense to perform a variety of experiments illustrating important principles upon which the science and practice of agriculture are based.

If to this material the school board or the pupils will add by purchase an 8-ounce glass graduate (10 cents), a simple magnifying glass (50 cents), a set of metric weights (\$1), 4 dairy thermometers (\$1), 6 student-lamp chimneys (90 cents), 12 5-inch test tubes (25 cents),

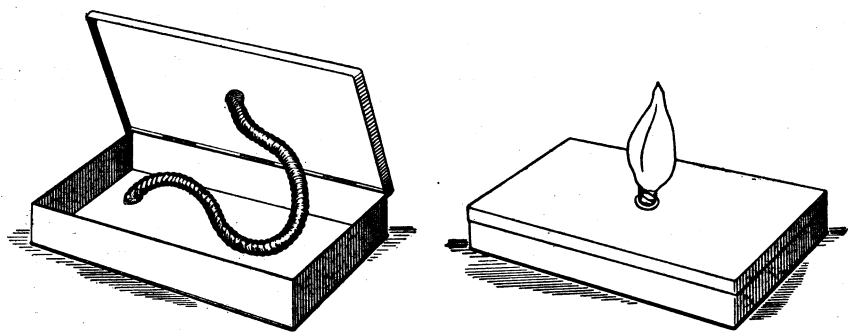


FIG. 1.—An alcohol lamp made from a tin-box.

a yard of thin muslin or cheese cloth (5 cents), a pint glass funnel (10 cents), a putty knife (15 to 25 cents), a grafting tool (50 to 75 cents), an alcohol lamp (25 cents), a kitchen scale with dial which will weigh from 1 ounce to 24 pounds (90 cents), 12 ordinary glass tumblers (30 to 50 cents), a yard of bicycle tire tape or surgeon's adhesive plaster, a yard of quarter-inch glass tubing, 3 large iron spoons, and a few ordinary plates, pie tins, etc., the school will be provided with an excellent equipment for the laboratory exercises included in this bulletin, and all at a cost of \$6 or \$7.

It will not be necessary to purchase all of the articles to which prices are attached in this list. In place of the putty knife, which would be used mainly as a spatula for mixing soils, a common, thin case knife or kitchen knife may be used. A heavy pocketknife may be used in place of the grafting tool.

The boys can easily make a fairly good alcohol lamp, as shown in figure 1, by punching a hole in the top of a tin box and inserting a piece of soft twine for a wick.

The wash bottle shown in figure 2 is a very convenient piece of apparatus, and is easily made from an empty bottle, a rubber cork with two holes through it, and two pieces of glass tubing. Hold the

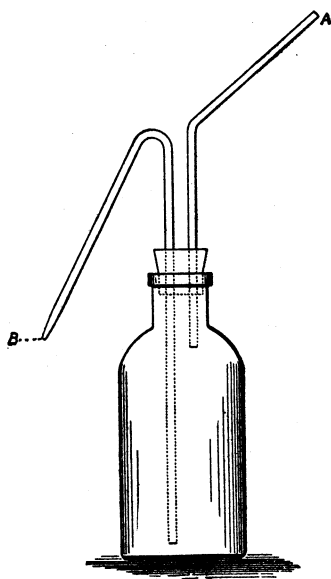


FIG. 2.—Wash bottle.

until a short section of it becomes red-hot, when it can be bent as shown in the illustration. An ordinary cork will do nearly as well as a rubber cork, and holes can be burned through it with a red-hot wire. The glass tubing should fit tightly in the cork. To operate the bottle, fill it two-thirds full of water and blow on it at A. Water will be forced out at B in a small stream, which can be directed against the inner surfaces of tumblers, test tubes, tin cans, etc., to wash down soil or sediment not easily reached in any other way.

The pupils should be encouraged to make and set up as much as possible of the apparatus. They should be taught how to melt off the tops of tomato cans neatly, how to make flats^a and other boxes out of packing boxes, how to make soil sieves by the use of wire screens on bottomless boxes, to make garden lines (fig. 3), stakes, and numerous other things that will be needed from time to time in these exercises. If one or two glass-covered frames like the one shown in figure 22 can be made soon after the opening of the fall term, the plants needed for indoor experiments can be grown much more easily and they can be protected better from cold. By mounting such frames on legs instead of brackets they can be moved from one window to another or at night can be moved away from the window to a warmer place. This work may be done at school if tools are available, otherwise at the homes of the pupils.

GENERAL PLAN OF LABORATORY EXERCISES.

No claim is made for the originality of these exercises. The attempt has been rather to arrange the work in a progressive and connected way, so that when completed it will give the pupils a

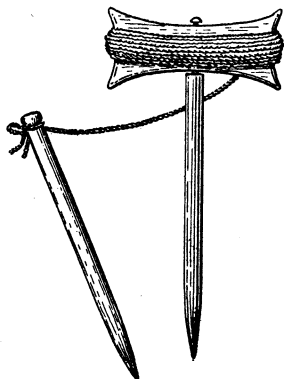


FIG. 3.—A homemade garden line.

^a A flat is a box about 2 feet wide, 3 feet long, and 3 inches deep, and is used for starting cuttings, seeds, etc.

fairly connected though necessarily imperfect view of the simpler phenomena of plant production. The order in which the different exercises are presented has been determined partly by the limits of the school year in the country and partly by the outline adopted by

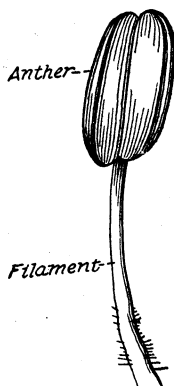


FIG. 4.—A stamen.

the committee on instruction in agriculture in its ninth report. The exercises are intended to extend over one school year—the seventh in an eight-grade school. The work will probably be taken up in the fall term, hence the desirability of beginning with plant work while plants are still growing out of doors. In winter when outdoor work with plants must be suspended in the great majority of rural schools, the pupils can take up the soil exercises, grafting, seed testing,

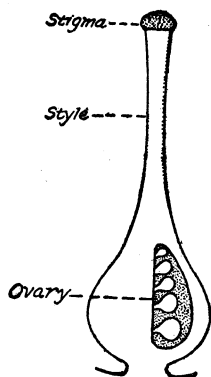


FIG. 5.—A pistil.

corn judging, etc., and be ready when spring opens for the study of corn and other field crops.

It is assumed that the pupils who are to take up elementary agriculture have had some nature-study work and in this way have learned something of the structure of common plants; that they know the names and understand to some extent the functions of the essential parts of common plants—roots, stems, leaves, and flowers, including the reproductive organs, stamens, and pistils (figs. 4, 5, and 6).

If the pupils do not have such knowledge, they should spend some time studying common plants like portulacas, morning glories, tomatoes, corn, squashes, and pumpkins, all of which can usually be found in blossom and in fruit at the opening of the fall term of school.

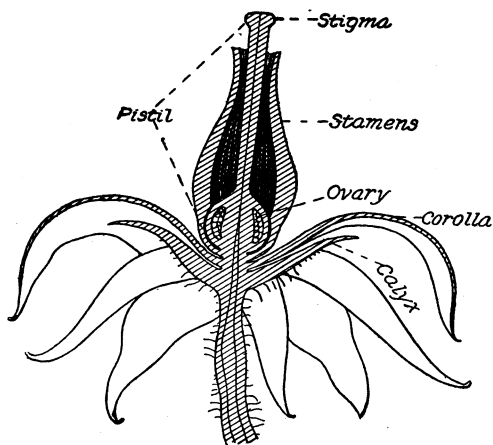


FIG. 6.—Vertical section of a tomato blossom. After Burkett et al. Agriculture for Beginners.

The teacher should consult some text-book on botany.

Having acquired a working knowledge of plant structure, in fact, while they are acquiring this knowledge, the pupils will begin to ask

what plants do—how they feed, grow, reproduce, etc., and this is where the exercises in this bulletin begin. The study of plants does not proceed very far before their dependence upon proper conditions of light, heat, moisture, air, soil, and other physical agencies becomes apparent; hence the reason for part 2 of this study—"The Environment of Plants."

Soils and climate therefore are not studied because of their fundamental importance, but because of their influence upon plant production.

EXERCISES IN PLANT PRODUCTION.^a

PART 1.—THE PLANT.

Exercise 1.—To Show That Plants Absorb Moisture from the Soil.

Take two 1-quart tin cans as near alike as you can get them and punch holes in the bottoms for drainage. Secure enough garden soil to fill both cans, mix it thoroughly, and sift it to remove pebbles and clods. Fill both cans level full of loose soil, which should then be packed by jarring each can three times on the table or floor. It is important to have the soil packed alike in both cans. Weigh the filled cans, and if one is heavier than the other, take out enough soil to bring them to the same weight.

Plant 5 or 6 kernels of corn in one can, water both cans alike, and set them aside for the corn to grow. Whenever water is applied to the can containing corn, an equal amount should be applied to the other can in order to keep both soils in about the same physical condition.

When the corn is 3 or 4 inches high, wet both soils thoroughly, allow the cans to stand until water ceases to drip from the bottom, weigh them, and record their weights separately. Set both cans in a warm light place where the corn will continue to grow rapidly. Weigh the cans twice on the following day—morning and afternoon—and record the weights. Keep this up for three or four days, or until the corn begins to suffer from lack of moisture. Water again and continue as before. You will probably find that the can containing the growing plants loses moisture much more rapidly than the other. Why? Compute the difference. As the corn increases in size does it use more or less water? How is the corn affected when the soil becomes too dry? What does it mean when corn in the field "rolls" or "curls?"

^a Notwithstanding the apparent simplicity of the exercises, there are many chances for failure unless the utmost care is taken to follow directions and to eliminate as far as possible all factors except those needed in the demonstration. The teacher ought to work out each exercise before attempting to present it to the pupils.

This experiment may be performed in another way by using flower pots instead of tin cans. When the corn is 3 or 4 inches high, get two lard pails or cans just large enough to take in the pots to their rims, as shown in figure 7. Mark on the outside of the pails the depth to which the pots will extend on the inside, and at a point 1 inch above each mark make a dent which can be distinctly seen on the inside of the pail. Now fill each pail with water up to the dent, water both pots thoroughly, and set them in the pails as shown in the figure. Set both pails and pots in a warm, light place so that the corn will continue to grow. The next day remove the pots, and you will probably find that the water is not up to the dents. What has become of it? From a previous experiment you will probably conclude that the soil has taken it up. From an 8-ounce graduate pour into one pail just enough water to bring it up to the dent again. Make a record of the amount necessary to do this. Fill the graduate and bring the water in the other pail up to the dent. Again record the amount of water used. Repeat these operations daily for two or three weeks. Find the total amount of water added to each pail.

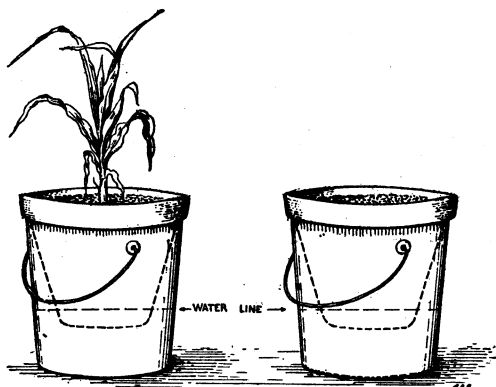


FIG. 7.—To show that plants absorb moisture from the soil.

How do the plants take up the water? The next exercise will show.

NOTE.—After starting exercise 1 prepare also exercise 3. Both exercises will require three or four weeks to show good results. While waiting for the plants to grow sufficiently to demonstrate that they get food and moisture from the soil the teacher should germinate some seeds as in exercise 11, so that when reference is made to root hairs in exercise 2 there will be root hairs to show the pupils. Do not at this time take up the other questions involved in exercise 11. Exercises 4 to 9, inclusive, may be taken up before the completion of exercises 1 and 3, if there is time for them.

Exercise 2.—How Roots Absorb Moisture.

(A)^a **Materials.**—Procure a wide-mouthed bottle, an egg, a glass tube 3 or 4 inches long and about a quarter of an inch in diameter, a candle, and a piece of wire about 5 inches long.

Experiment.—Remove a part of the shell from the large end of the egg without breaking the skin beneath. This is easily done by gently

^a After Goodrich. Nature Lessons for School and Farm. Hampton Normal and Agricultural Institute.

tapping the shell until it is full of small cracks and then picking off the small pieces. In this way take the shell from a space about one-half inch in diameter. Remove the shell from the small end over a space as large as the diameter of the glass tube. Next cut from the lower end of the candle a piece about one-half inch long; bore a hole in this just the size of the glass tube. Now soften one end of this

piece of candle and then stick it onto the small end of the egg so that the hole in the candle comes over the hole in the shell. Heat the wire and with it solder the piece of candle more firmly to the egg, making a water-tight joint. Place the glass tube in the hole in the piece of candle and with the hot wire solder it firmly. Now run the wire down the tube and break the skin of the egg just under the end of the tube. Then fill the bottle with water until it overflows and set the egg on the bottle, as in figure 8. In an hour or so the white of the egg will be seen rising in the glass tube, because the water is making its way by osmosis into the egg through the

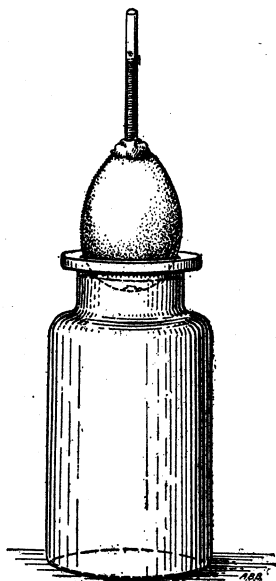


FIG. 8.—To show osmosis.

skin, which has no opening so far as can be found with the most powerful microscope. In this way water laden with plant food enters the slender root hairs of plants.

This process of osmosis may also be shown as follows: Remove the shell from the large end of an egg without breaking the skin, break a hole in the small end of the egg and empty the shell, rinse it out with water, fill the bottle with colored water, fill the egg partly full of clear water, and set it on the bottle of colored water. Colored water will gradually pass up into the egg and color the water that is there. Or the colored water may be put into the eggshell at the start and the clear water in the bottle. In that case coloring matter will pass from the shell to the bottle.

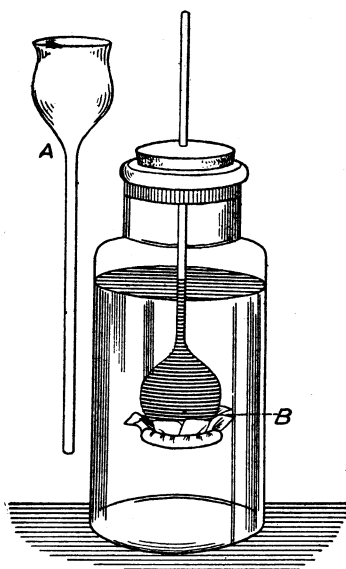


FIG. 9.—Osmosis shown with bladder membrane.

(B)^a The method by which plants absorb moisture through their roots can be shown in another way by the use of the apparatus in figure 9. Tie a piece of moistened bladder over the large end of the thistle tube *A*, as shown at *B*, previously filling the tube partly full of molasses. Insert the tube in the cork of a wide-mouthed bottle and immerse it in clear water, as shown in the accompanying illustration. In the course of a few hours water will pass through the bladder and force the molasses out of the top of the tube.

Of what importance is it to know that the roots of plants take up moisture from the soil? Does this have anything to do with the feeding of plants?

Exercise 3.—To Show that Plants Get Food from the Soil.

Secure about 2 quarts of clean sand and heat it in a shovel or iron pan until all vegetable matter is burned out. Fill two large tin tomato cans, or other similar vessels, having holes in the bottom for drainage, with this soil and plant in each 5 large, plump beans as near alike as possible, which have been soaked overnight. Water both cans with rain water and set them in a warm place for the beans to grow.

After this treat both cans alike, except that one is to be watered with rain water and the other with soil solution.^b After the beans are up pull out all but 3 of the strongest plants in each can. Continue watering one can with rain water and the other with soil solution for four or five weeks. By that time the beans in the latter should be much larger and stronger than the others. To what is this difference due? Surely not to differences in temperature or light or soil or the rain water. It must be mainly due, then, to something dissolved from the rich soil and carried in solution to the roots of the beans, which in turn pumped it up to the stem and leaves of the beans.

Plant food in the soil is dissolved by water and by weak acids given off by the root hairs much in the same way that sugar and salt are dissolved. In this condition plant food can be taken in by the roots as easily as pure water, and water may be rich in plant food and yet remain as clear as pure water. We think of the "clear-as-crystal" well water that we drink as being pure water, but we know that often it contains so much lime that every few weeks we have to chip off the scale of lime on the inside of the teakettle.

^a After Burkett, Stevens, and Hill. Agriculture for Beginners.

^b To make the soil solution, fill a lard pail two-thirds full of rich garden soil or, better, rich soil from beneath a manure heap, and add enough rain water to make a thin slop. Stir this thoroughly and set it aside until water is needed for the beans, then strain off some of the water, using a piece of thin muslin or cheese cloth for a strainer. A new solution should be made up about once a week.

Well water may also contain other substances in solution. Suppose you try an experiment to show this by fastening sprouted kernels of wheat on thin slices of floating cork in such manner that the roots will hang over the edges of the cork down into the water. Put some of the seedlings thus arranged into a tumbler of clean rain water and others into a tumbler of clean well water and watch their development.

Exercise 4.—To Show that Plants Give off Moisture.

Take a plant that is well started in a tomato can or flower pot, a piece of cardboard, and a glass tumbler or jar large enough to cover the plant. Cut a slit in the cardboard and draw it around the plant as shown in figure 10. Seal the slit with pitch, wax, or tallow so that no moisture can come up through it from below; cover the plant with the glass and set it in a warm, sunny place. Moisture will condense on the inner surface of the glass.^a Where does it come from? Is all the moisture absorbed by the roots given off in this way? How can you find out? Why do plants need water?

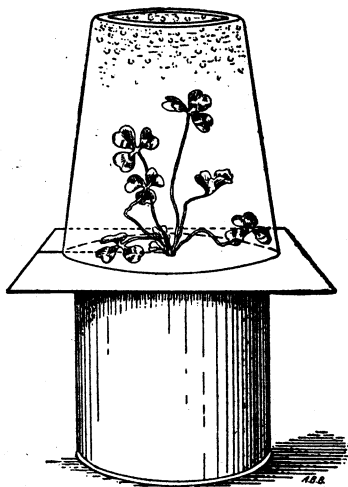


FIG. 10.—To show that plants give off part of the moisture absorbed from the soil.

Exercise 5.—To Show the Rise of Water in Plants.

That the water absorbed by the roots of plants is forced upward through the plants can be demonstrated by severing the stem of a geranium 3 or 4 inches from the surface of the soil, setting on top of the cut end of the stem

a section of glass tubing several inches long, and fastening the two together by wrapping the joint with a strip of adhesive tape or surgeon's plaster. Keep the root of the plant normal by supplying it with water. Note what happens inside the glass tube, making observations every few hours.

Exercise 6.—Circulation of Water in Plants.

To show that water and whatever substances it holds in solution circulate to all parts of the plant, fill a tumbler about one-third full of lukewarm water colored with a few drops of red ink or some

^a If moisture does not condense readily inside the glass, cool the glass by exposing it to a current of cold air or by wrapping it for a minute or two in a cloth wrung out of cold water. The outside of the glass should then be dried so that the moisture on the outside will not obscure that within.

other brilliant coloring matter, and place in the colored water the freshly cut stems of white carnations, white roses, lilies of the valley, or other white flowers, or the twigs of trees with young leaves on, or almost any soft green plant. Be sure that they are fresh. In a short time the colored water will rise through the stems or twigs and may be seen distributed in vein-like patterns through the petals of the flowers or through the leaves. Hold the leaves up to the light and the coloring matter can be seen more clearly. In this manner the stem of the plant carries food in solution which has been absorbed by the roots.

Exercise 7.—To Show that Part of the Moisture Absorbed by the Roots of Plants is Retained in the Plant.

Pull up any good-sized green plant like a bunch of clover or a pig weed, weigh it carefully, and record the weight. Now put it in a pie tin, tomato can, or other metal receptacle, and set in the bright sunlight until it is thoroughly dry and brittle. Weigh again and by comparison with the first weight determine what percentage of the plant was water.^a Using this result as a basis for calculation, how many pounds of green clover will it take to make a ton of clover hay?

Put the dried plant in an oven or on top of a stove over a slow fire which will not char the plant and see if any more moisture can be driven off.^b What are the percentages of dry material and water as finally determined? We have found that part of the water taken up by the roots is given off by the leaves and part of it is retained—enough to make up a large percentage of the weight of herbaceous plants. It has been found that corn roots take up over 300 pounds of water for every pound of dry matter produced, while oats and clover take up over 500 pounds of water for every pound of dry matter. The plant food is therefore taken in very dilute form.

Exercise 8.—To Show that Plants Get Food from the Air.

Take two or three small pieces of green wood a half inch or less in diameter (short sections of a small twig will answer), put them into a test tube or a covered pressed-tin box with small holes in the top to allow the escape of smoke and gas, and hold over a hot fire until all gas and smoke have been driven off. Do not allow them to blaze. What remains? What color is it? Apply a match to one of the pieces. Does it burn with a flame? Will it burn at

^a If the school scales do not weigh small amounts accurately it would be well to use more green material.

^b A safer plan than that above would be to heat the dried plant for several days in a double boiler, such as is used in the kitchen for cooking oatmeal. Such a boiler can be rigged up in the schoolroom by hanging a small pail containing the dried plant inside a larger pail partly filled with water.

all? It answers to the description of charcoal, which is almost pure carbon. Boil the carbon in water and in weak acid (vinegar) to see if it can be dissolved in either of these liquids. Do you think that the roots of plants could take up much of this material?

Put a tablespoonful of sifted soil (from a pot in which a plant has been growing) in an iron spoon and heat it red hot. Was there much material to burn in the soil, much carbon? Not enough will be found to supply plants with all they need of this material, which constitutes nearly one-half of their solid material. It must come mainly from some other source.

Now put the charred sticks into an iron spoon and heat them until only ash remains. What has become of the carbon? It has combined with an invisible gas, oxygen, to form another invisible gas, carbon dioxid, or carbonic-acid gas, which mixes with the air and from which the plant may take it in through the leaves. The leaves

discard most of the oxygen, but the carbon is sent to all parts of the plant and built into the new structure representing the season's growth.

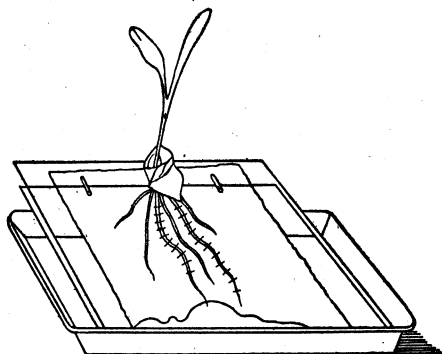


FIG. 11.—To show where roots increase in length.

Exercise 9.—How Plants Grow.^a

To show where roots increase in length, place some kernels of corn or other large seeds between the folds of a piece of wet cloth. Keep the cloth wet till the seeds have sprouted and the young plants have roots

2 or 3 inches long. Have at hand two panes of glass about 5 by 8 inches, a piece of cloth a little longer than the width of the glass and about 3 inches wide, a spool of dark-colored thread, and a shallow pan or dish. Lay one pane of glass in the pan, letting one end rest on the bottom and the other on the opposite edge of the pan (fig. 11). Wet the cloth and spread it on the glass. Take one of the sprouted seeds, lay it on the cloth, tie pieces of thread around the roots at intervals of one-fourth inch (tie carefully so that the roots will not be injured), or, if waterproof ink is available, mark the roots with a fine pen at intervals of one-fourth inch; place the second pane of glass over the roots, slipping in a sliver of wood to prevent crushing them, and letting the upper edge of this glass come just below the seed. Fold the corners of the cloth about the seed, put half an inch of water

^a After Goodrich. *Nature Lessons for School and Farm.* Hampton Normal and Agricultural Institute.

into the pan, and leave for development. A day or two will show conclusively where the lengthening takes place. Has this fact any bearing on the relation of soil texture to root development? The soft, tender root tips will force their way through a mellow soil with greater ease and rapidity than through a hard soil, and the more rapid the root growth the more rapid the development of the plant. Here is the lesson of deep plowing and thorough breaking and pulverizing of the soil before the crop is planted.

The growth of the stem of plants can be shown in a similar way by tying pieces of thread around the stem and branches of any plant at intervals of one-fourth inch, or marking them with ink. Measure carefully from time to time the distance between the threads and the distance from the top thread to the tip of the plant to determine whether the stem elongates or the plant makes its growth mainly at the tip.

Propagation.

Plants propagate by means of spores (as smut, puffballs, molds, ferns, and toadstools), seeds (corn, bean, and lettuce), root sprouts (locust, poplar, and plum), and by division. Some of the plants which propagate by division divide naturally and some artificially. Natural separation of parts occurs in plants which reproduce by means of rhizomes or root stocks (June grass, quick grass, and iris), bulbs (onion and lily), corms (crocus and gladiolus), tubers (potato, dahlia, and Jerusalem artichoke), detached tips of branches (water milfoil and some varieties of willow), stolons (strawberry), and layers (black raspberry and Forsythia). Artificially the principal ways of propagating plants are by means of layers, cuttings, buds, and grafts. Many of the plants mentioned, and others also, propagate in two or three different ways.

Have pupils try experiments in tip layering with black raspberries (fig. 19), in vine layering with grapevines (fig. 20), and in mound layering with currant or gooseberry bushes (fig. 21).

Exercises in grafting and budding can be conducted indoors to secure facility in performing these operations by bringing in large branches of green trees for stocks and securing the necessary scions and bud sticks in the usual way. The stocks may be prepared for budding by boiling to loosen the bark, and trimmed bud sticks may be preserved for winter use in dilute alcohol. The pupils should be given practice in as many methods of propagating plants as possible.

Exercise 10.—Spores.

The development of molds from spores can be followed easily by cutting a potato in two, rubbing lightly the freshly cut surface of one half with a piece of moldy bread and putting it on a plate under an

inverted tumbler. Keep this covered potato in a warm but rather dark place for several days, examining it every few hours to note progress in the growth of the mold.

In two or three days there ought to be a heavy growth of mold. By examining this closely the pupils will be able to see little globular spore cases growing at the tops of slender branches which spring up from a network of whitish, threadlike material. Observe these spore cases closely to see if any change occurs in them as they mature. Much more pleasure can be had from the study of molds if a microscope is available, but all that has been mentioned in this exercise can be seen with the naked eye.

The little rusty spots seen near the margins of some fern leaves are spore cases. When you step on a puffball it sends up a cloud of spores.

Exercise 11.—Seeds—Germination Test.

Count out 50 or 100 seeds of the kind to be tested^a and place them in a plate between two folds of moistened canton flannel or thin blotting paper (fig. 12). On a slip of white paper record the variety,

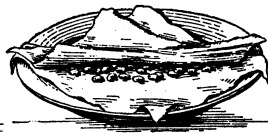
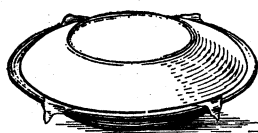


FIG. 12.—Seed-testing device.

number of seeds, and the date, then place it on the edge of the plate. Cover the whole with another plate or a pane of glass to prevent too

rapid evaporation of moisture. Set the plate in a warm room (68° to 86° F.) and examine the seeds every twenty-four hours for six or eight days.^b If they get too dry add enough water to moisten, not saturate, the cloth or blotting paper. At the end of the test count the sprouted seeds and from them determine what percentage of the whole number of seeds is good. With large seeds no difficulty will be experienced in using the folds of canton flannel, but with small seeds the blotting paper is better.

Study the root hairs, which will show plainly if dark-colored cloth is used in the seed tester.

^a In official germination tests 100 seeds are used of peas, beans, corn, and other seeds of similar size, and 200 seeds of clover, timothy, cabbage, wheat, and other small seeds.

^b For most seeds six days are enough for the test, but beets, buckwheat, cotton, cowpeas, onions, redtop, tomatoes, and watermelons should be allowed to remain eight days; salsify and spinach ten days; carrots, celery, parsnips, and tobacco fourteen days, and blue grass and parsley twenty-eight days.

Exercise 12.—To Make a Balance.

A balance suitable for weighing small articles can be made easily and cheaply. Such a balance can be made sensitive to the weight of one-fourth of a postage stamp, and capable of sustaining a weight of several ounces. It is made chiefly of wood. All the parts are common articles and only ordinary tools are required. Only certain features require careful attention; in other respects rough work is permissible.

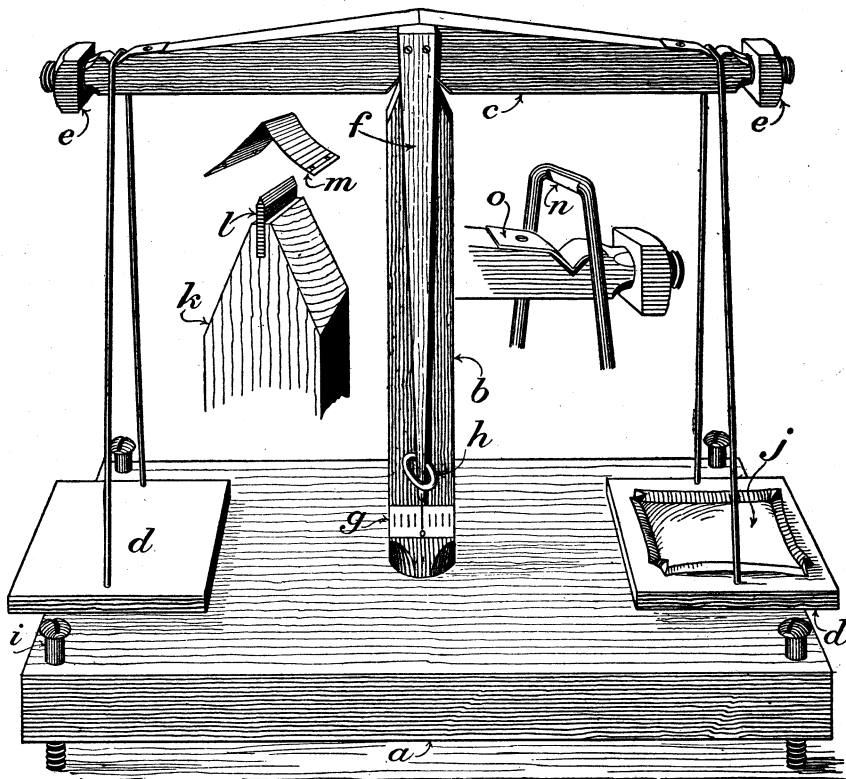


FIG. 13.—A simple balance.

The essential parts of a balance (see fig. 13) are the base (a), the pillar (b), the beam (c), and the trays or pans, as they are usually called (d, d). The beam is balanced by means of the balancing nuts (e, e). The pointer (f) indicates on the scale (g) the effect of weights on the trays. A screw eye (h) encircling the pointer serves to hold the beam at rest or permits it to swing as desired, according as the screw eye is turned. Four screws (i) at the corners of the base serve to level the balance.

In making the balance thoroughly dry, soft, pine wood is preferable. Screws are preferable to nails. The base is 12 or 14 inches

long by 7 inches wide and 1 inch thick. The pillar is 1 inch square and about 9 inches high. It can be set in an inch hole in the center of the base. Care should be taken to have it stand perpendicular to the base. The upper end of the pillar is beveled on the right and left sides, as shown at *k*. A slot is sawed in the end to receive a knife edge, as shown at *l*. The beam is made from a stick 1 inch square and about 10 inches long. Its lower face is left straight; the other faces are beveled from the center to the ends, which are left three-eighths or one-half inch square. A notch 1 inch wide and one-half inch deep is accurately cut in the center of the flat or bottom face. This receives the central bearing (*m*) of the beam. An inch from each end of the beam a notch one-fourth inch deep is cut to receive the tray bearings. Each end is rounded to receive the balancing nuts. The nuts should cut well-defined threads in the wood and move easily and smoothly. Applying a little soap to the threads helps this. A strong pointer (*f*) is firmly fastened to the beam by two or more screws. Its lower end is provided with a needle, colored black so as to be readily seen. The screw eye (*h*) is placed near the end of the pointer and in the center of the pillar. It should turn easily and smoothly. When the balance is otherwise completed, turn the screw eye so as to hold the pointer firmly, then paste to the pillar back of the pointer a strip of white paper (*g*) bearing scale marks one-sixteenth inch apart, with the 0 mark of the scale directly back of the needle.

The three bearings of the beam are the most exacting features of the construction. Each consists of a knife edge acting within a groove formed of bent tin. The knife edge (*l*) for the central bearing may be made of a pocket or case knife blade or of a piece of hard brass filed to a straight, sharp edge. The knife edges for the end bearings are made by filing the lower side of the tray wires where they cross the beam, producing a straight, sharp edge (*n*) about three-fourths inch long. The tins forming the grooves of the bearings are made of thin tin, such as is used in oyster and vegetable cans. Bright pieces are selected. The central bearing requires a strip 1 inch wide and 2 inches long (*m*). It is bent across at the middle, the bend being lightly hammered flat on a flatiron. The ends are then separated. The halves of the strip curve somewhat, leaving a narrow angle at the bend. This tin is firmly held in the central notch of the beam by four small screws. The tin strips for the end bearings are about one-half inch wide. They are bent in the same way as the other. One end of the strip is longer than the other, and is punched to receive a single screw holding it to the beam, as shown at *o*. The bending of the tin strips roughens the surface of the groove. It must be polished by rubbing the back

of the point of a knife blade back and forth in the groove for some time. To insure success the grooves must be very narrow to prevent side slipping, yet not so narrow as to bind on the knife edge. The highly polished groove and sharp knife edges produce the least friction and increase the sensitiveness of the balance.

The tray wires are made of common No. 12 wire. The trays are 3 by 3 inches and one-fourth inch thick. Two holes near opposite edges receive the wires, which are bent in opposite directions beneath the trays, thereby holding them firm and level. If the trays tend to swing from front to back of the balance, the tins of the bearings may be slightly twisted by inserting a knife blade under them.

The balance can now be tested for use. When in working condition the pointer will slowly swing back and forth many times and finally come to rest at 0 of the scale. It probably will not do this at the first trial. Set the balancing nuts at about equal distances from the ends of the beam, then stand tacks along the lighter beam arm until the two arms nearly balance. The tacks are then driven in permanently. If tacks are too light, use brads or screws. The final balancing can then be done by properly moving one or both of the nuts. The proper adjustment of the balancing nuts should be tested each time the balance is used.

Weights and objects to be weighed can be held on the trays by cardboard dishes (*j*). A pair of forceps can be made from a strip of spring brass or even of hickory wood, the points being properly sharpened.

A set of metric weights ranging from 20 grams to 1 centigram and suitable for use with this balance can be had for \$1 or less.

Exercise 13.—Seeds—Purity Test.

It is as important to plant pure seeds as it is to plant seeds that will grow. Many of the smaller seeds, such as clovers and grasses, frequently contain seeds of troublesome weeds and inert material like chaff, sticks, broken seeds, etc.

To make a purity test, secure one or more samples of red clover, alsike clover, or alfalfa seed, preferably of different trade grades, and examine them for impurities. Mix the seed thoroughly and weigh out 5 grams of the mixture. Spread this sample thinly on a piece of white paper. By means of a magnifying glass (fig. 14) separate the seed with a knife blade into three parts—one containing only pure seed of the kind being tested, another consisting of seeds other than pure seed, as adulterants or weed seeds, and the third consisting of inert materials, as sticks, gravel, broken seeds, etc. By weighing these parts separately and comparing their weights with that of the original sample the percentage each of pure seeds, of weed seeds, and

of inert materials is readily determined. Slight loss in weight during careful testing is usually due to the loss of fine inert matter.

It is sometimes important to know the character of the foreign seeds. If an adulterant like yellow trefoil is present, it should be recognized. It may be of interest to determine its amount separately. Certain weed seeds are especially undesirable, as dodder, Canada thistle, chicory, wild carrot, etc. If present, these should be counted and their number per pound estimated according to the weight of the sample tested. Farmers' Bulletins 260 and 382 will be helpful in determining adulterants and weed seeds.

The pure seed may contain many shriveled seeds. It would be of interest to know how the weight of 100 of these seeds compares with that of an equal number of plump seeds. A question may arise as

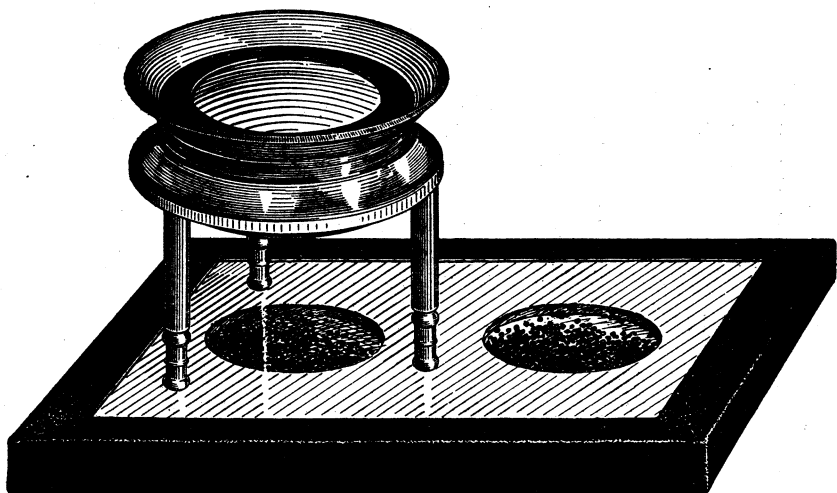


FIG. 14.—A serviceable tripod magnifying glass and a convenient mount for preserving seeds for study.

to the value of such shriveled seed. Again, the relative weights of the smallest and largest seeds in the sample may be determined. See how equal numbers of large and small seeds compare in weight.

It may be well to consider the relative chances of large and small seeds in producing a crop under adverse seeding and weather conditions. If the pure seed consists in part of bright seed and in part of dull, reddish-brown seeds, it is evidently a mixture of new and old seed. Make a number of germinating tests to determine these matters.

In making a germinating test of such seed the seeds to be tested are counted indiscriminately from the pure seed lot.

It is of especial interest in such tests to consider the different trade grades offered by large dealers. After making complete tests of different grades compare their quality with their price, bearing in

mind that more than 95 per cent of the sample should be pure seed, and more than 95 per cent of the pure seed should germinate promptly.

Exercise 14.—Development of Young Plants from Seeds.

The development of young plants from seeds may be observed very nicely by planting seeds against the sides in tall bottles or in a box with glass sides, as shown in figures 15 and 16. Suppose, for example, that you put an inch of soil in the bottom of the box shown in figure 15 and then put a kernel of corn on top of the soil close to the glass at one end of the box and a bean at the other end of the

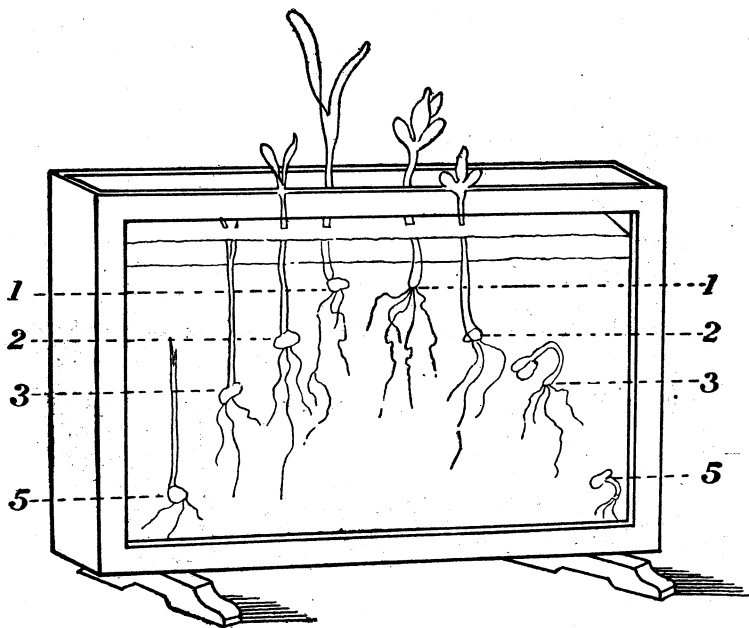


FIG. 15.—Device showing proper depth to plant seeds.

box. Then put in another inch of soil, another kernel of corn, another bean, and perhaps also a clover seed near the glass in the middle of the box. Continue in this way until the box is filled. Water the soil thoroughly, cover the glass sides of the box with black cloth or paper to exclude the light, and set it aside to allow the seeds to germinate.

You will doubtless find that some very large seeds will germinate and send leaves to the surface from a depth of 5 or 6 inches in a light sandy soil, but that this depth is not so favorable for their development as a depth of 2 or 3 inches. Try to find the best depth for planting a few large seeds and a few small seeds like radishes, clover,

lettuce, etc. Planting seeds against the side of the glass in this way will enable you and the pupils to examine them from time to time and see what becomes of those which do not reach the surface.

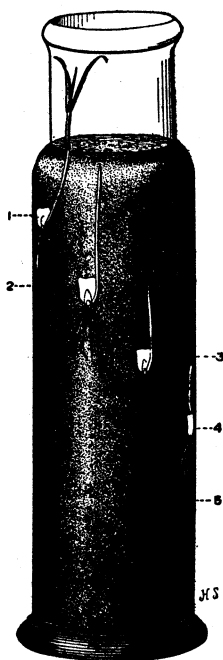


FIG. 16.—To show the best depths at which to plant corn.

(A) Why do some flowers produce fruit or seed while others do not? Why do some ears of corn have vacant places on the cob—places where there are no kernels? This can be answered by an experiment in the school or at home. Find a hill of corn on which an ear is just starting, and before any silk pushes out of the husk tie a paper or muslin bag over the ear in such a way as to exclude all pollen and insects. Leave this on for several weeks; then examine the ear to see if any kernels of corn have developed. The application of pollen to the pistil of a flower is called pollination.

The necessity of pollination for the production of fruit can be shown by another, somewhat more difficult, experiment. Carefully open the flower bud of an apple, a tomato, or other flower having

Exercise 15.—To Show that Young Plants Get Food from Seeds.

Much of the food of very young plants comes from the seeds to which they are attached. To prove this, plant two beans in a tin can containing sandy soil; water and keep in a warm, light place. Soon after the beans push above ground take a sharp-pointed knife and carefully cut off the two half beans (cotyledons) without injuring the rest of the plant. (See A, fig. 17.) Allow the plants to grow for a week or two and note the more rapid development of the plant to which the cotyledons are attached.

Have the children try similar experiments at home with squash seeds or Lima beans.

Exercise 16.—Pollination.

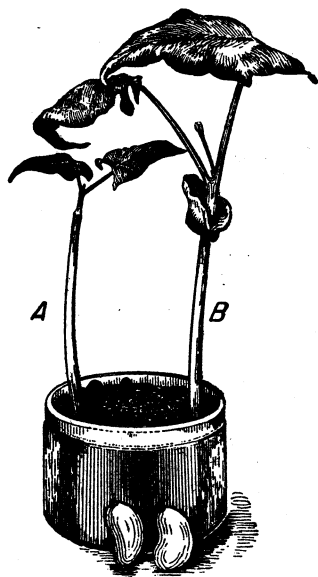


FIG. 17.—Plant food in seeds. After Graham, Ohio Agr. Col. Ext. Bul., Vol. I, No. 8, p. 10. Beans planted in rich black earth on the same day. Both plants came up on the same day. The half beans were removed from one. The other grew faster because the half beans furnished food.

both stamens and pistil, when it appears to be just ready to blossom, and remove all of the stamens, using care not to injure the pistil or stigma (fig. 18). Without removing the flowers from the parent plant inclose all of them in small white muslin bags in such way that no insects can get in. At the same time prepare other flowers of the same kind, in the same way, except that pollen from another flower of the same kind is in each case dusted on the pistil of the flower inclosed. After a week or ten days remove the bags and see what has happened to the flowers. You will probably find that all of the flowers not dusted with pollen have withered and dropped off without producing any fruit, while the others have begun to develop small fruits.

From this it will be seen that it is necessary, in order for a flower to produce fruit, that its pistil receive pollen either from the same flower or from some other closely related flower. This pollen is carried by the wind and by bees, flies, and other insects, but some-

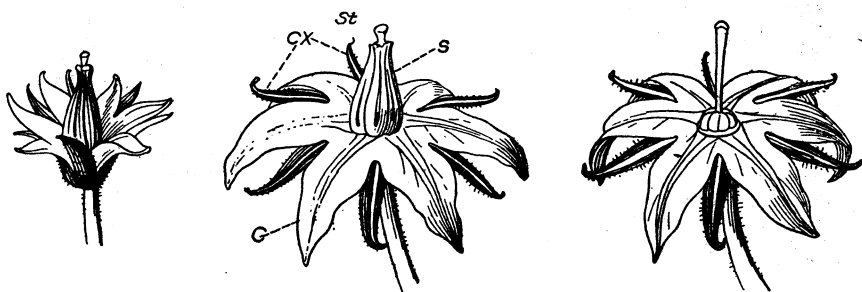


FIG. 18.—Tomato blossom ready to pollinate. At the left a partly opened bud, in the middle an opened blossom, at the right an opened blossom with anthers removed.

times none of these agencies succeed in bringing the right kind of pollen to the flower, and it withers and drops off.

In the case of corn each silk protruding from the husks is a pistil, and if any one of these silks fails to receive pollen the kernel of corn down at the lower end of the silk will not be developed.

(B) Have the children plant a few hills each of field corn and pop corn side by side in the school garden or at home. In the autumn when the corn is husked notice the mixture of two kinds of kernels on the same cob. How did the corn mix? It is by putting the pollen of one kind of plant on the pistil of another closely related and excluding all other pollen that plant breeders sometimes originate new varieties.

Exercise 17.—Layering.

Layering may be considered the connecting link between natural and artificial propagation. Many plants, such as black raspberries, grapes, Forsythias, and others, increase naturally in this way, but

man has lent his aid in so many ways to this process of propagation that it may be considered to a certain extent artificial.

A layer is a branch so placed in contact with the earth as to induce it to throw out roots and shoots, thus producing one or more independ-

ent plants, the branch meanwhile remaining attached to the parent plant. Layering frequently proves a satisfactory method of multiplying woody plants which do not readily take root from cuttings.

Tip layering.—The tip of a branch or cane is bent down to the ground and slightly covered

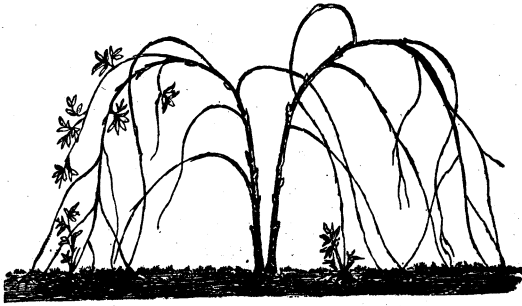


FIG. 19.—Tip layering.

with soil, when it will throw out roots and develop a new plant (fig. 19). Many plants can be propagated in this way. The black raspberry is a familiar example.

Vine layering.—A vine is stretched along the ground and buried throughout its entire length in a shallow trench, or it may be covered in certain places, leaving the remaining portions exposed. Roots will be put forth at intervals and branches thrown up. Later the vine may be cut between these, leaving a number of independent plants (fig. 20). The grape can be easily propagated in this way.

Mound layering.—Plants which stool,

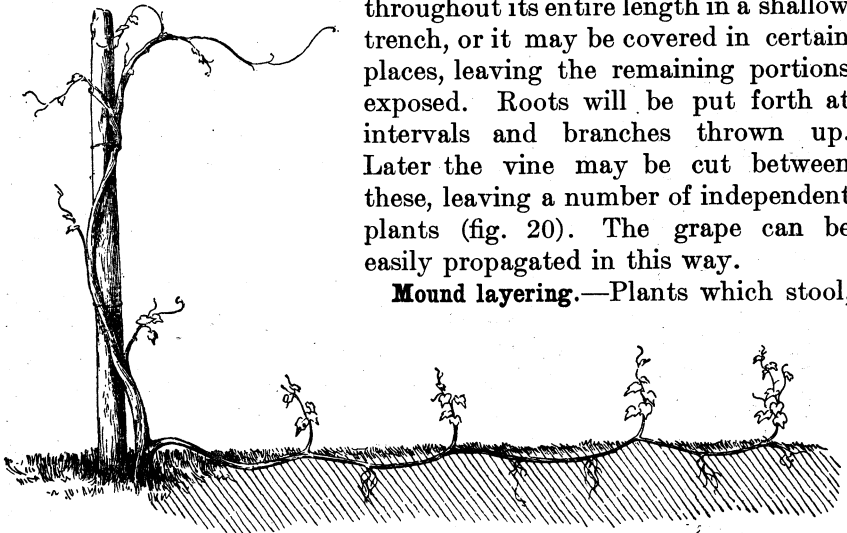


FIG. 20.—Vine layering.

sending up a large number of stems or shoots from a single root, are often layered by mounding up the earth so as to cover the bases of these stems and cause them to throw out roots (fig. 21). Each may then be removed from the original root and treated as an independent

plant. A plant is often cut back to the ground to make it send up a large number of shoots to be layered in this way.

Facilities for Rooting Cuttings.

In order successfully to root cuttings of coleus, geraniums, fuchsias, roses, and begonias in the school-room it will be an advantage to have a broad window box constructed somewhat as follows: Make a frame about 15 or 20 inches wide, 8 inches high at one side and 12 inches high at the other, and as long as the width of the window in which it is to be used. Place a tight bottom in the frame,

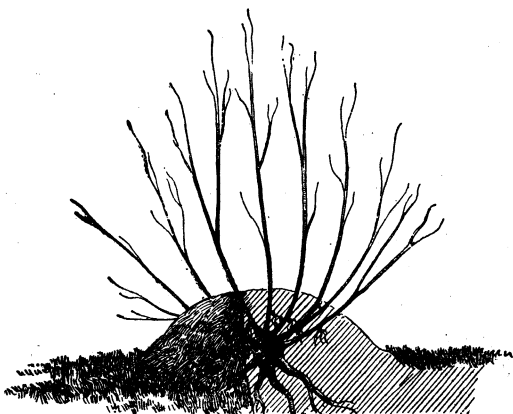


FIG. 21.—Mound layering.

thus making a box similar to that shown in figure 22. Provide three or four holes one-half inch in diameter in the bottom of the box to allow the escape of any excess moisture. Place about 1 inch of broken pots, coarse gravel, or clinkers in the bottom of the box, and on top of these place a layer of clean sand free from clay or decaying organic matter, about $2\frac{1}{2}$ to 3 inches thick. Over the top place panes of glass, so as to make a close but well-lighted chamber within the frame. Place the cuttings in this frame. By using care in watering and providing ventilation by the partial removal of the glass as necessity requires under such treatment, fair results should follow. Some experience will

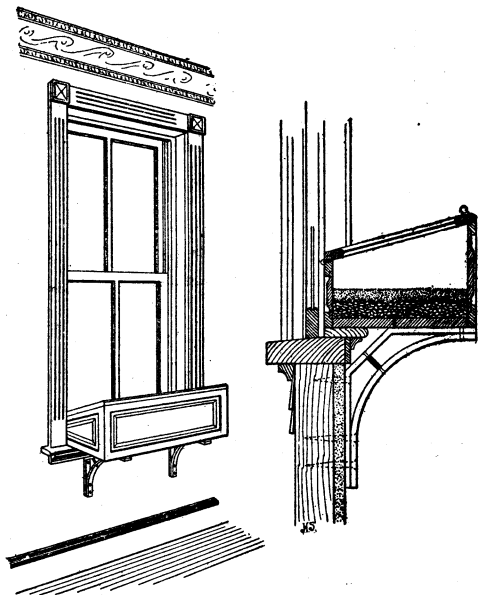


FIG. 22.—Frame for rooting cuttings.

be necessary to successfully root plants even with this device, but much better results may be expected than without it.

Exercise 18.—To Make Soft Cuttings.

Soft cuttings may be made from either the leaf or stem. Some plants, such as the Rex begonia and wax plants, may be propagated by inserting the edge of a leaf or even a piece of a leaf (fig. 23) in sand and supplying it with plenty of moisture and warmth; or a leaf may be laid flat, right side up, on the surface of the sand and fastened down by splinters through the veins at intervals (fig. 24). Plants will spring up at the broken edges of the leaf or at cut places in the veins.



FIG. 23.—Leaf cutting—part of leaf.

Stem cuttings are readily made from the coleus, geranium, verbena, tomato, and numerous other herbaceous plants. Take thrifty shoots from any of these plants and divide them into cuttings having at least two nodes and several leaves; reduce the leaf surface to about one-half to check evaporation; insert the cutting in moist sand about one-half of its length and press the sand firmly around it. (See fig. 25.)

Exercise 19.—To Make Hard Cuttings.

Hard cuttings may be made from dormant mature wood of last season's growth of privet, grape, barberry, willow, and many other plants. Make the cuttings 4 to 6 inches long so as to include at least two nodes. They may then be rooted

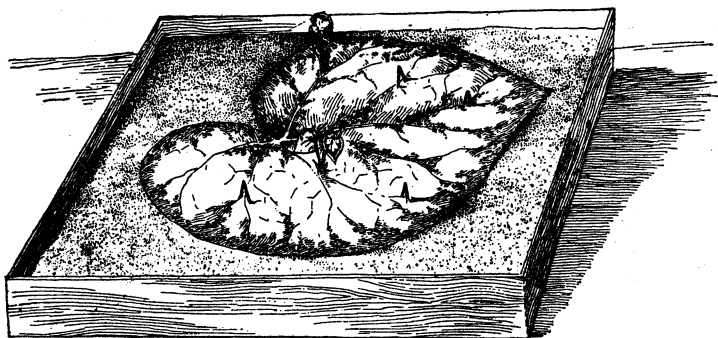


FIG. 24.—Leaf cutting—whole leaf.

in the same way that soft cuttings are rooted, or, if prepared in autumn or winter for planting out of doors next spring, they may be tied in bundles of about 50, using care to keep all tips in one direction and butts in the other. These bundles should be buried

out of doors or put in moist sand or sawdust in the cellar, placing tips down. In the spring prepare a trench in sand or sandy loam, as shown in figure 26, set in the cuttings about 6 inches apart, and pack earth tightly around them. Keep the surface of the soil free from weeds and mellow throughout the summer, water in dry times, and it is likely



FIG. 25.—Stem cutting or "slip" of coleus.

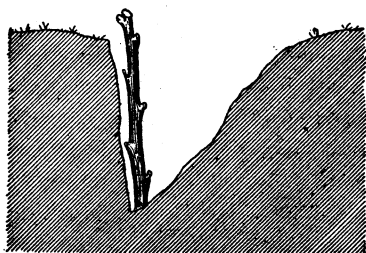


FIG. 26.—Cutting set in trench.

that a large percentage of the cuttings will root and grow. There are various modifications of the simple cutting, as shown in figure 27.

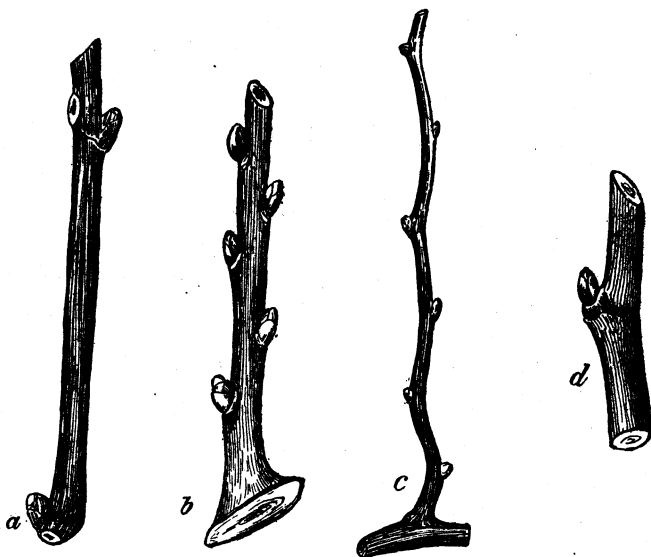


FIG. 27.—Cuttings: *a*, Simple cutting; *b*, heel cutting; *c*, mallet cutting; *d*, single-eye cutting.

Exercise 20.—To Make Grafting Wax.

A good grafting wax may be made of the following ingredients:
Resin, 4 parts; beeswax, 2 parts; tallow or linseed oil, 1 part—by

weight. If a harder wax is needed, 5 parts of resin and $2\frac{1}{2}$ of beeswax may be used with 1 part of tallow.

The resin and beeswax should be broken up fine and melted together with the tallow. When thoroughly melted the liquid should be poured into a vessel of cold water. As soon as it becomes hard enough to handle it should be taken out and pulled and worked until it becomes tough and has the color of very light-colored manila paper. If the wax is applied by hand, the hands should be well greased, tallow being the best material for this purpose. The wax may be applied hot with a brush, but care is necessary in order to avoid injury.

The wax should be spread carefully over all cut or exposed surfaces and pressed closely, so that upon cooling it will form a sleek coating impenetrable to air or moisture.

Waxed string may be prepared by putting a ball of No. 18 knitting cotton into a kettle of melted grafting wax. In five minutes it

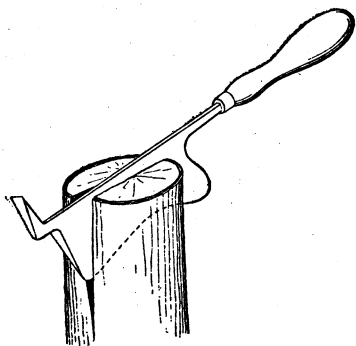


FIG. 28.—Grafting tool.

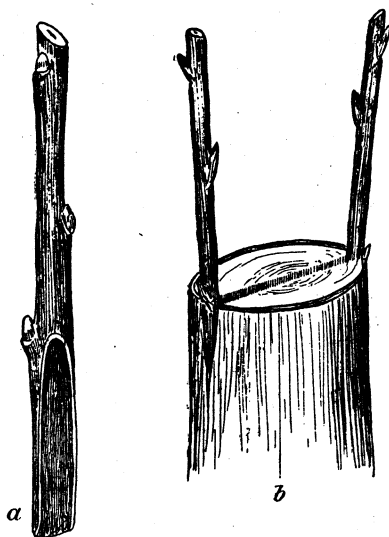


FIG. 29.—Cleft grafting: *a*, Scion; *b*, scions inserted in cleft.

will be thoroughly saturated, after which it will remain in condition for use indefinitely.

Exercise 21.—Cleft Grafting.

To make a cleft graft select a branch 1 or $1\frac{1}{2}$ inches in diameter and sever it with a saw. Care should be taken that the bark be not loosened from any portion of the stub. Split the exposed end with a broad thin chisel or grafting tool (fig. 28). Then with a wedge or the wedge-shaped prong at the end of the grafting tool spread the cleft so that the scion (fig. 29, *a*) may be inserted (fig. 29, *b*).

The scion should consist of a portion of the previous season's growth of the tree to be propagated and should be long enough to have two or three buds. The lower end of the scion, which is to be inserted into the cleft, should be cut into the shape of a wedge, having the outer edge thicker than the other (fig. 30). In general it is a good plan to cut the scion so that the lowest bud will come just at the top of this wedge (fig. 29, *a*) in order that it will be near the top of the stock. The advantage of cutting the wedge thicker on one side is illustrated in figure 30, which shows how the pressure of the stock is brought upon the outer growing parts of both scion and stock, whereas were the scion thicker on the inner side the conditions would be reversed, and the death of the scion would follow.

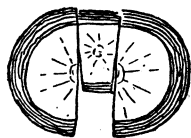


FIG. 30.—Cross section of stock and scion.

The importance of having an intimate connection between the growing tissues of both scion and stock can not be too strongly emphasized, for upon this alone the success of grafting depends. To make this contact of the growing portions doubly certain, the scion is often set at a slight angle with the stock into which it is inserted, in order to cause the growing portions of the two to cross.

After the scions have been set, the operation of cleft grafting is completed by covering all cut surfaces with a layer of grafting wax.

Cleft grafting is particularly adapted to top-working old trees, that is, changing them from undesirable to desirable varieties. Branches too large to be worked by other methods can be cleft grafted. Sometimes several varieties are grafted on a single tree. The best time for cleft grafting is in the spring just after growth has begun. Wood for scions is usually cut in the fall, tied in bundles, and buried in sand to protect them from extremes of heat and cold until they are to be used.



FIG. 31.—Whip grafting: *a*, The stock; *b*, the scion; *c*, stock and scion united.

Exercise 22.—Whip Grafting.

To make a whip graft, cut the stock off diagonally—one long smooth cut with a sharp knife, leaving about three-fourths of an inch of cut surface, as shown in figure 31, *a*. Place the knife about one-third of the distance from the end of the cut surface, at right

angles to the cut, and split the stock in the direction of its long axis. Cut the lower end of the scion in like manner (fig. 31, *a* and *b*), and when the two parts are forced together, as shown in figure 31, *c*, the cut surfaces will fit neatly, and one will nearly cover the other if the scion and stock are of the same size. A difference in diameter of the two parts to be united may be disregarded unless it be too great. After the scion and stock have been joined they should be wrapped with 5 or 6 turns of waxed cotton to hold the parts firmly.

This is the process used almost exclusively in the production of young nursery stock by means of root grafting.

The roots are dug and the scions are cut in the autumn and stored. The work of grafting may be done during the winter months. When the operation has been completed the grafts are packed away in moss, sawdust, or sand, in a cool cellar, to remain until spring. It is important that the place of storage be cool, else the grafts may start into growth and be ruined, or heating and rotting may occur. If the temperature is kept low—not above 40° F.—there will be no growth except callousing and the knitting together of stock and scion. In spring the grafted plant is so set as to bring the union of stock and scion below the surface of the ground.

Top-grafting may also be done in this way, but whenever the union is above ground it must be protected, as in cleft grafting, by either a coating of grafting wax or a bandage of waxed muslin.

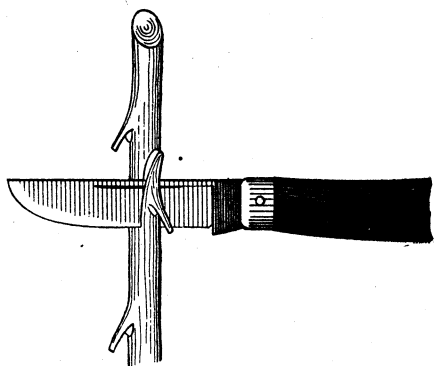


FIG. 33.—Cutting the bud.

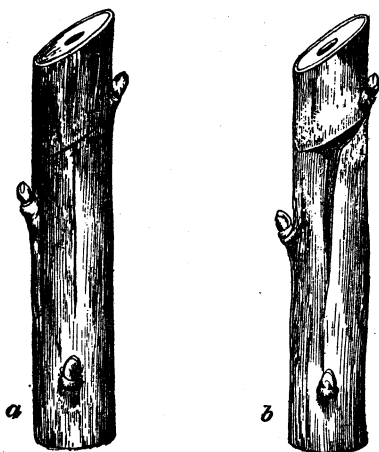


FIG. 34.—Budding: Preparing the stock.

Exercise 23.—Budding.

Budding is one of the most rapidly performed and economical forms of artificial propagation. The work of budding is done during the

season of active growth—July, August, or early September. The bud should be taken from strong, healthy twigs of the present season's growth. The bud sticks (fig. 32) are prepared so that the petiole or stem of each leaf is left attached to serve as a handle to aid in inserting the bud beneath the bark of the stock. The bud should be cut as in figure 33, paring off a small portion of the woody tissue with the bud.

The stock for budding should be at least as thick as an ordinary lead pencil. With the apple and pear a second season's growth will be necessary to develop this size, while with the peach a single season will suffice. To bud a plant make a T-shaped cut through the bark for the reception of the bud, as shown in figure 34, *a*.

Loosen the flaps of bark caused by the intersection of the two cuts (fig. 34, *b*) with the ivory heel of the budding knife, grasp the bud by

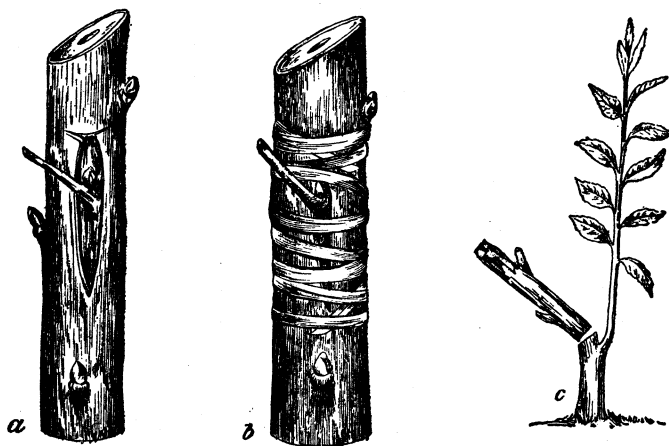


FIG. 35.—Budding: *a*, Inserting the bud; *b*, tying; *c*, cutting off the top.

the leaf stem as a handle, insert it under the flaps, and push it firmly in place until its cut surface is entirely in contact with the peeled body of the stock (fig. 35, *a*). Tie a ligature tightly about it, above and below the bud, to hold it in place until a union shall be formed (fig. 35, *b*). Bands of raffia or wrapping cotton, about 10 to 12 inches long, make a most convenient tying material. As soon as the buds have united with the stock the ligature should be cut in order to prevent girdling the stock. This done, the operation is complete until the following spring, when all the trees in which the buds have "taken" should have the top cut off just above the bud (fig. 35, *c*).

PART 2.—THE ENVIRONMENT OF THE PLANT.**Exercise 24.—Conditions Essential to Plant Growth—Light.**

To show that light is an important factor in plant growth call the attention of the pupils to the way in which plants growing in a poorly lighted room stretch toward the nearest window. Recall how potatoes sprouting in the cellar send their sprouts sometimes for a yard or more in the direction of the light. Notice the struggle of forest trees to send their branches up to the light. There will be exceptions, of course—some trees and shrubs which seem to do well under the cover of other trees, but in the main those trees which are shut off from the direct rays of the sun do not thrive. It will be an instructive object lesson to visit a forest and notice how on the edge of the woods the large limbs on all of the trees are on the side next to the open field. Why do trees growing in the thick forest become so much taller and more spindling than trees of the same variety growing in the open field? Does this habit of trees have any important economic bearing? Are trees with long, straight, clean trunks more or less valuable for timber than trees with low, bushy tops?

The influence of light on plant growth may be shown experimentally as follows: Plant two pots with corn. Place one in a window where it may make a normal growth. Give the other the same temperature and the same attention as regards watering, but place it under a paper cone or box through which light can not penetrate. Contrast the appearance of the two sets of plants grown under these conditions. After the plants under the cone or box have attained a height of 2 or 3 inches, remove the covering and note what takes place when the pot is placed in full sunshine.

Exercise 25.—Conditions Essential to Plant Growth—Heat.

Numerous opportunities will occur to show the importance of heat as a factor in plant growth. Seeds may be planted in two pots or tin cans which are treated exactly alike in every way except that one pot is kept where the temperature ranges from 60 to 80° F., while the other is kept in a temperature 20 to 40° cooler. The latter may germinate, but there will be a marked difference in the time of germination and in the vigor of the plants.

In the spring or fall when the weather is cool, but not frosty, radish seeds may be started indoors in two boxes about a foot square and 8 or 10 inches deep, with 3 inches of good soil in the bottom. As soon as the young plants are well started remove all but 5 or 6 of the strongest plants in each box, then set the boxes side by side out of doors. Cover one box with a pane of glass, leaving a small crack for

ventilation, but aside from this treat them exactly alike. Water when necessary. Put a thermometer in each box in such a position that temperatures can be read without disturbing the boxes. Take and record temperatures several times daily for a week and observe differences in the development of the plants. Draw conclusions concerning the relation of heat to the growth of plants.

Exercise 26.—Conditions Essential to Plant Growth—Moisture.

Take two pots or tin cans in which plants are growing. Put them under like conditions except that water is withheld from one for several days. Have pupils draw conclusions as to the importance of moisture to plant growth.

Exercise 27.—Conditions Essential to Plant Growth—Air.

Air is necessary in the soil in order to make it a congenial place for the growth of plants.



FIG. 36.—Method of demonstrating the effect of too much water in soil.

(A) The necessity for air can be demonstrated very nicely by taking some ordinary garden soil which is rather retentive in nature—that is, contains a considerable percentage of clay—and placing an equal quantity in each of two tumblers, as shown in figure 36. In one plant seeds of beans or peas in the usual fashion, and in the other plant the

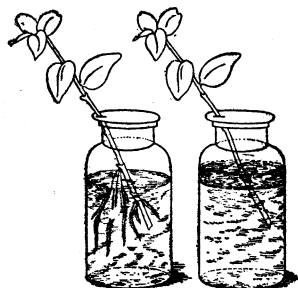


FIG. 37.—Arrangement for showing the effect of the exclusion of air on plant growth.

same kind of seeds in the same way, but keep the soil constantly saturated with water, so that there is a thin stratum of moisture over the surface of the soil. The seeds in the first tumbler will undoubtedly germinate in a short time, while the seeds in the other tumbler will require a longer time to germinate, and if the temperature of the room in which the two glasses are kept is low the seeds will rot. The tumbler which contains an excessive amount of moisture prevents the access of air that is necessary to the germination of the seed, while the one which is kept only moderately moist allows a sufficient amount of air to come in contact with the seeds to insure germination.

(B) The necessity of air for the development of roots can be demonstrated by using two bottles similar to those shown in figure 37. After filling them two-thirds full of water which has been boiled to drive out the air, place a cutting of coleus, geranium, or willow in the receptacles, as indicated, but over the surface of the water in one

bottle pour a thin layer of oil—castor oil or sweet oil—and observe the behavior of the cuttings.

Exercise 28.—Soil Collection.

Have each pupil in the class bring samples of all the leading types of soils to be found on his home farm or, if not living on a farm, in the near vicinity of his home. Quart samples will be large enough. Empty each sample out on a separate sheet of heavy tough paper. Compare the different samples. Bring those which seem to be very much alike together, so as to reduce the number of samples. Provide enough boxes to hold the different kinds of soil, and in these store the soils for future use. In nearly every locality the pupils will be able to secure samples of sand, clay, loam, and peat or muck, and an effort should be made to have these four types represented in the school collection.

Exercise 29.—Classification of Soils.

The teacher will select a sample of dry soil from each of his most typical soils (sand, clay, loam, and peat) and put them side by side in pans or on plates where the pupils can examine them. All lumps should be broken up with a potato masher or rolling-pin or other piece of wood. The pupils should now examine the different soils and take notes concerning them.

Examine the samples as to color and fineness, rub the particles between the thumb and forefinger. Which are the coarsest?

Wet a handful of each soil and mix it in the hand. Which crumbles or falls apart most easily after wetting? Which is most sticky?

Take four tumblers nearly full of water. Into one put 10 grams of sand, into another the same weight of clay, into another loam, and into another peat. Stir all thoroughly and set them aside to settle. Which settles most quickly? Which most slowly? Stir them again and set them aside. After one minute pour off the liquid. Allow the settled portions to dry thoroughly and then examine them. It will be found that in each case the sediment consists largely of rather coarse particles of sand. Weigh each dried sample and find what percentage of the original 10 grams of each soil consists of sand. Which soil contains the largest percentage of sand?

Put 10 grams of peat in a large iron spoon or in a test tube and heat it red-hot. What happens? Test the other soils in the same way. The part that burns is humus or decayed vegetable matter. Which soil contains the largest percentage of humus?

From the data at hand have the pupils write a description of each class of soil.

Exercise 30.—Light and Heavy Soils.

Clay is called a heavy soil and sand a light soil. Does this refer to the weight of the soils?

Weigh a quart of dry, finely pulverized packed clay and a quart of dry packed sand. Which is heavier? Light and heavy as applied to soils are terms which refer to the ease or difficulty with which they can be plowed or cultivated.

Exercise 31.—Porosity—The Capacity of Soils to Take in Rainfall.

Break the bottoms off 5 long-necked bottles,^a tie a small piece of cheese cloth or thin muslin over the mouth of each and arrange them in a rack with a glass tumbler under each, as shown in figure 38.

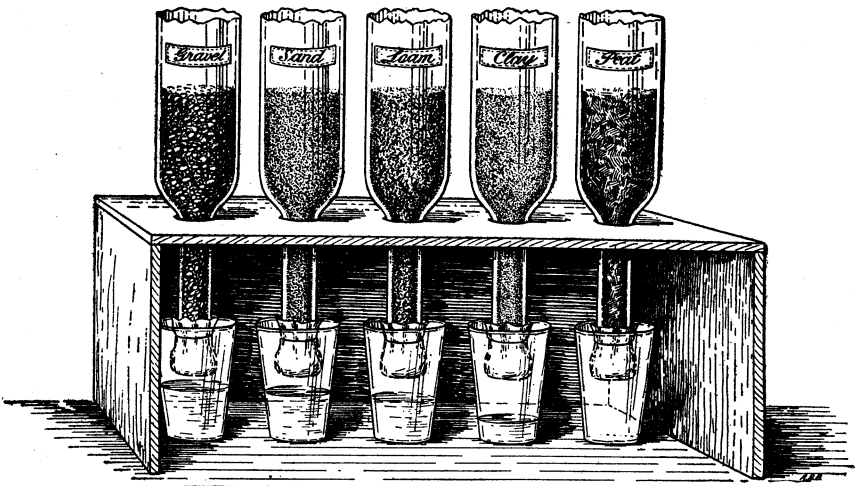


FIG. 38.—Apparatus to test the capacity of soils to take in rainfall.

Fill the bottles to about the same height with different kinds of soil—gravel in one, sand in another, etc.—and firm the soils by lifting the rack and jarring it down moderately three or four times. Now, with watch or clock in hand, and with a glass of water held as near as possible to the soil, pour water into one of the bottles just rapidly enough to keep the surface of the soil covered and note how long before it begins dropping into the tumbler below. Make a record of the time. Do likewise with each of the other bottles and compare results. Which soil takes in water most rapidly? Which is the most porous? What happens to the less porous soils when a heavy shower of rain comes? How can a soil be made more porous? Repeat the

^a To break the bottom off a bottle file a groove in the bottle parallel with the bottom. Heat a poker red-hot and lay it in the groove. As soon as a small crack starts from the groove draw the poker around the bottle and the crack will follow.

experiment with one of the soils, packing the soil tightly in one bottle and leaving it loose in the other. What is the effect of packing? Does this have any bearing on farm practice?

Which soil has the greatest capacity to hold water? This can be determined from the above experiment by emptying and replacing each tumbler as soon as all free water has disappeared from the upper surface of the soil above it. After water has ceased dripping from all the bottles measure and compare the water in each tumbler. Which soil continued dripping longest? Which would drain most readily?

Which soil would store up the greatest amount of moisture? This can be determined from the same experiment by weighing each bottle before and after filling it with dry soil, and again after water has entirely ceased dripping from it. The difference between the weight of the dry soil and that of the wet soil is the weight of water stored. During the time that the bottles are dripping, which may take several days, they should be covered to prevent evaporation of water from the surface of the soils.

Make other practical applications of the principles brought out in this exercise.

Exercise 32.—Air in Soils.

In Exercise 27 it was shown that air is necessary in soils for the proper development of plants. To determine the percentage of air space in different soils, put a pint of loose soil into each of three cans—sand in one, clay in another, and loam in another. Now pour water very slowly from a graduate into each can until water just shows at the top of the soil. Pour the water in at one place, leaving the rest of the surface dry so that the air can escape from the soil. When the soil is full of water the space formerly occupied with air is filled with water. How much water did it take to fill this space? Your graduate will tell you. Compute the percentage of air space in each soil.

Plan an experiment to determine the percentage of air space more accurately by weighing the soil and the water used.

Exercise 33.—Capillarity—The Power of Soils to Take up Moisture from Below.

Arrange 4 or 5 student-lamp chimneys, as shown in figure 39, and tie cheese cloth or thin muslin over their lower ends. Fill each with a different kind of dry soil, as in Exercise 31. Pour water into the pan beneath until it stands about half an inch above the lower end of the chimneys, then observe the rise of water in the different soils. Make notes on the height to which the water rises and on the time it takes. In which soil does the water rise most rapidly; in which

to the greatest height? Which soil draws up the greatest amount of water? How can this be determined? Which soil would dry out soonest? Which would be able to bring moisture from the greatest depth? This power of soils to raise water from below is called capillarity. It is an important function, for by it plants are able to get moisture and plant food from the subsoil in times of drought.

If chimneys are not to be had, this experiment can be performed with the apparatus shown in figure 38 by substituting the pan for the tumblers, or the experiments performed with the bottles can be performed with the chimneys and tumblers.

If more accurate tests of capillarity are desired, it will be necessary to procure a series of glass tubes at least 3 feet high, for in some soils water will rise to that height, or even higher.

Exercise 34.—Puddling.

Some soils if cultivated immediately after a heavy rain will puddle, i. e., pack so closely that when they dry out they bake into a hard, almost impenetrable, condition.

Fill four tomato cans half full—one with sand, another with clay, another with loam, and another with peat. Add water, and stir until the soils are about the consistency of paste. Set them aside ten or fifteen minutes. Pour off the free water and stir again. Set them in the sunlight and allow them to dry thoroughly, or, better, set them over a slow fire for several hours. Which soils baked? Which could be most easily stirred or cultivated after drying? In farm practice which could be worked soonest after a rain without danger of puddling? Which could be worked earliest in the spring?

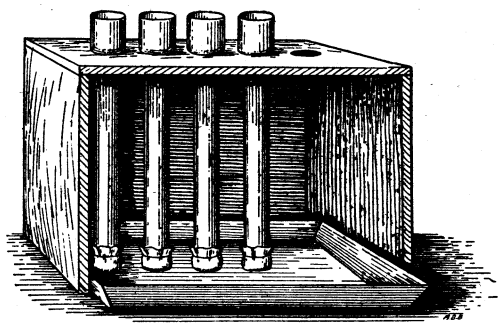


FIG. 39.—Apparatus to test the power of soils to take up moisture from below.

Exercise 35.—The Effect of Lime on Clay Soils.^a

(A) Take a vessel holding a pint or more and fill it with clear well water. Put into it a couple of spoonfuls of fine clay soil and stir up thoroughly for three or four minutes. Let it settle for five minutes. Then take two clear glass bottles, holding about a half pint each, and fill them with water from the vessel, being careful not to stir up the sediment again. Into one of the bottles put a piece of lime about

^aAfter Fisher. Practical studies in Agriculture for Public Schools. Purdue University.

as large as a bean and shake the contents well. Put nothing in the other bottle. Set the two bottles aside and notice any difference or changes that take place in an hour or two and over night.

(B) Take two deep dishes or other vessels and fill them with fine clay soil. Into one put a couple of teaspoonfuls of lime, according to the size of the dish. Put no lime in the other dish. Stir up both lots of soil with water until they are thoroughly sloppy. Set them where they will dry out. When they are completely dry remove the cakes of soil from the dishes and pulverize. What differences do you notice? Can you explain these differences? Do the results in the bottles help you to understand the action of the lime in the soil? Could you expect a similar result from putting lime on stiff clay soil? Do you think it would be a good idea to try it?

Exercise 36.—Action of Frost on Soils.

Puddle a pint of stiff clay, mold it into a ball, and bake it on the stove. In freezing weather moisten this ball and put it out of doors over night. If it does not break up the first night, moisten it again and subject it to the action of frost. What happens? From this result what would you say of the practice of fall plowing heavy clay land? Is there any advantage in fall plowing aside from the action of frost on the soil?

Exercise 37.—Temperature of Soils as Affected by Color.

Sink a box about 2 feet long by 1 foot wide and 8 or 10 inches deep into the soil so that the top is even with the surface of the ground. Fill the box with the lightest-colored sand you can find. Cover half of it with a thin layer of lampblack—just enough to blacken the whole surface. Insert the bulb of one thermometer about one-half inch under the surface of the uncolored sand and another one-half inch under the surface of the colored sand, and on a sunny day take readings of the thermometers, every hour from daylight until two or three hours after sunset.

Perform a similar experiment with peat or the darkest-colored soil you can find, except that half of this soil is colored white with lime dust. Take readings as before. Compare results. What conclusions may be drawn as to the influence of color on the temperature of soils? Are the differences recorded in sunlight as marked as when the sun is not shining? Other conditions being equal, which soil would soonest be warm enough for planting in the spring?

The influence of color upon temperature may be illustrated in a simple way by scattering lampblack or dark-colored earth on snow when the sun is shining.

Exercise 38.—Temperature as Affected by Moisture.

Take two tomato cans and in the bottom of one punch a number of holes for drainage. Fill both with the same kind of soil. Wet the soils thoroughly. Insert the bulb of a thermometer an inch under the surface of each and set them in direct sunlight. Take readings from each thermometer every two hours for two or three days, and record the temperatures. Compare the readings and see what results follow as the moisture disappears from the can provided with drainage.

What is the conclusion as to the temperature of drained and undrained soils? Which would be the earlier soil in spring? Which the later as the fall rains start in? Would there be a tendency to shorten or to lengthen the growing season by draining wet soils?

Exercise 39.—Temperature of Soils as Affected by Inclination of the Surface or Exposure to the Sun.

Fill three boxes, about a foot square and 6 or 8 inches deep, with the same kind of soil and set them in the sunlight side by side with the same exposure, except that one is level, one tilted about 30° to the south, and the other tilted about 30° to the north. Insert the bulb of a thermometer about one-half inch under the surface of the soil in each box, take readings every hour during a sunny day, and compare results. In which box were the highest temperatures recorded? Ask pupils to explain this. What practical bearing has this upon the selection of farms? With other conditions alike, which would be ready to work earlier in the spring, a north slope or a south slope?

Exercise 40.—Free Moisture in Soils.

Take four slender baking-powder cans of the same size, with tops and bottoms removed, and tie over one end of each a piece of cheese cloth or thin muslin.

Fill one can to within an inch of the top with coarse dry sand, another with dry loam, the third with dry pulverized clay, and the fourth with dry muck or leaf mold mixed with sand. Weigh the soils before putting them into the cans, in order to have a record of the weights for use in the next experiment. If any of the soils contain pebbles or clods, these should be removed by sifting. Set the cans where they can drain readily into separate vessels; then have four pupils pour water slowly into each can until it begins to drip from the bottom, using care not to have any water stand on the surface of the soils when the dripping begins. Allow the cans to stand until all drip has ceased. Measure or weigh the drainage from each can. This is free water—the water which would be removed from soils by thorough underdrainage.

From which soil was the greatest amount of drainage collected? Does the amount of drainage water appear to have any relation to the fineness of the soil? Which soil drained the most rapidly? Do soils underlain with sand (having a sandy subsoil) need underdraining as a rule?

Exercise 41.—Capillary Moisture in Soils.

As soon as all drip from the soils used in Exercise 40 has ceased weigh each can, and by comparing this weight with the dry weight of the same soil determine how much moisture has been held by each soil. The difference in each case represents approximately the capillary moisture in the soil—that is, the moisture which is held in suspension between the soil particles.

Which soil retained the greatest amount of capillary moisture? This was what per cent of the dry weight? Does the amount bear any relation to the fineness of the soils? To the amount of organic matter? Find the volume of your cans and estimate how many pounds of water per cubic foot each soil is capable of holding. What does it represent in inches of rainfall?

Capillary moisture and film moisture (see Exercise 42) are supposed to dissolve from the surface of soil particles plant food which is taken up by the roots of plants. Does a fine or a coarse soil present a greater amount of surface to the action of water? Does the fineness of a soil then bear any relation to its fertility? What?

The teacher can illustrate the increase of surface due to fineness of division by taking an inch cube of wood and dipping it in ink. Show the pupils that it now presents a surface of 6 square inches; split it in two and show them the 2 square inches of uncolored surface which have been added by division. Have seedlings of radishes growing in a box of sandy soil. Pull some of these up and show how the root hairs cling to the particles of soil.

Exercise 42.—Hygroscopic Moisture in Soils.

The presence of hygroscopic or film moisture in soils may be demonstrated by spreading out and air-drying thoroughly one of the soil samples used in the preceding exercises; then putting a small portion of it into a test tube and heating it to a high temperature. If any moisture condenses on the inside of the tube it is hygroscopic or film moisture from the soil. Or weigh out 10 grams of air-dry soil, put it in an iron spoon, heat it red hot, and again weigh it. From the weights before and after heating determine the film moisture.

Exercise 43.—The Influence of Tillage and Mulches on the Retention of Moisture in Soils.

Fill four lamp chimneys, prepared as in figure 39, or better, four 12-inch lengths of 4-inch down-spouting or conductor pipe prepared in a similar manner, with fine garden loam to within 2 inches of the top. Immerse these tubes for a few seconds in water. Cover the surface of the soil in one tube with $1\frac{1}{2}$ inches of the same kind of soil, and pack it down. Cover another with $1\frac{1}{2}$ inches of the same kind of soil, and keep it loose by stirring from time to time. Cover another with $1\frac{1}{2}$ inches of road dust, and another with $1\frac{1}{2}$ inches of chaff or finely cut straw. Suspend the tubes where drainage will be free and where all will be subjected to the same conditions as to sunlight and currents of air. Weigh them morning and evening for three or four days.

Which tube lost moisture most rapidly? Which most slowly? What is the conclusion as to the influence of cultivation or mulches upon the retention of moisture in the soil? Is the destruction of weeds the only object sought in cultivating crops?

Exercise 44.—To Show the Effect of Plowing Down Manures and Clods.^a

Fill three chimneys or tin cylinders, prepared as in Exercise 43, three-fourths full of fine dry soil. On top of this soil in one chimney pack 1 inch of finely cut, dry straw, on another 1 inch of well-rotted straw or manure, and on the other 1 inch of hard clay broken into pieces about the size of large peas. Fill the chimneys with more fine dry soil and set them in a pan containing a half inch or so of water. Keep water in the pan all of the time. Note the rise of water in the chimneys. Does it pass through the dry straw or clods as quickly as it does through the rotted material? The straw and rotted manure represent material plowed under and lying in the bottom of the furrow, and the clods represent a hard baked surface plowed under. The soil on top represents the furrow slice. Apply this experiment to farm practice. In which condition do you think a crop would suffer least from dry weather? When should strawy manure be plowed under, spring or autumn? When hard baked clay? Why? (See Exercise 36.)

Exercise 45.—Influence of Drainage upon Plant Growth.

We have learned from Exercise 38 how the amount of moisture in the soil, or, in other words, how drainage affects the temperature. The influence of drainage upon plant growth can be shown by planting corn, beans, or almost any seed in the same kind of soil in two tomato

^a Adapted from Fisher. Practical studies in Agriculture for Public Schools. Purdue University.

cans, one with holes punched in the bottom and the other without. Apply the same amount of water to each can from day to day, and observe the condition of the plants for two or three weeks.

As soon as any marked difference in favor of the drained soil is manifested in the condition of the growing plants, seal the holes in the bottom of the drained can with paraffin or wax, and punch holes in the bottom of the other can. Continue to apply water as before and note any changes that occur.

Exercise 46.—Effect of Manures on Plant Growth.

In this exercise wheat is to be grown for three weeks on soils treated in different ways. The first thing to do is to put about 150 or 200 plump kernels of wheat in the seed tester (fig. 12) so that it will be sprouted by the time the soil is ready for planting.

Now secure enough sandy or sandy loam soil to fill 8 common tumblers or drinking glasses. Pulverize the soil, mix it thoroughly and divide it into 4 equal parts, putting each fourth into a granite or earthenware pan, and numbering the pans 1, 2, 3, and 4.

The soil in pan No. 1 should be used as a check, that is, it should not be treated with any fertilizer or manure. It will thus serve as a means of comparison to show the effect of applying manures to the other soils.

The soil in pan No. 2 should be treated with nitrogen as follows: Secure from a druggist or a fertilizer dealer a small quantity of nitrate of soda and dissolve one level teaspoonful of this material in 2 quarts of clean rain water. Take 1 ounce of this solution (measured in a graduate or an ounce bottle) and sprinkle it carefully over the whole surface of the soil in pan No. 2. Sprinkle enough more clean rain water over the soil to wash the nitrate of soda into the soil.

To the soil in pan No. 3 add as much dry finely pulverized barnyard manure as can be put (without packing) in a 10-gauge shotgun shell. With a case knife or clean glass rod mix the manure thoroughly with the soil. Sprinkle the soil with clean rain water as in pan No. 2.

Green manure is to be added to the soil in pan No. 4. To prepare this dig up a number of plants of clover, alfalfa, or cowpeas, and carefully wash all dirt from the roots. Select two or three plants having nodules (small irregular knots formed by nitrogen-gathering bacteria) on the roots and run them (root and top) through a meat chopper or sausage grinder, or chop them with a chopping knife until they become a shredded pulpy mass. Do not lose the green watery juice that is squeezed from the plants in grinding or chopping, but mix it in with the pulp. To the soil in pan No. 4 add a 10-gauge shotgun shell twice full of this pulp, mix thoroughly, and wash down as directed for pan No. 3.

Place the four pans in the sunshine and leave them for about twenty-four hours.

On the following day bring the soil in the different pans to the proper condition of moisture—just wet enough to hold together after squeezing in the hand, but not so wet that water can easily be squeezed from it. Fill two tumblers to within one-half inch of the top from each pan. The tumblers filled from pan No. 1 should be labeled “No. 1, check,” those from pan No. 2, “No. 2, nitrogen,” those from pan No. 3, “No. 3, barnyard manure,” and those from pan No. 4, “No. 4, green manure.”

From the seed tester select five strong, well-sprouted grains of wheat for each tumbler. Make a straight groove one-quarter inch deep in the soil of each tumbler and place in it at regular intervals the five selected grains of wheat, using care to set the kernels with the sprouts right side up and all facing one way, so that the plants will all come up regularly at about the same time. Cover the grains and set the tumblers in a light, warm place.

Allow the plants to grow three weeks. Water them each day, but do not use enough water to soak the soil. The tumblers have no drainage and if water stands in the bottom of the tumblers it will shut out the oxygen needed by the roots of the plants.

At the end of the three weeks compare the plants in the four sets of tumblers as to color, vigor, height of plant, and root development.

Judging by the condition of the plants, was the soil improved by the application of a manure? Which treatment gave the best result? Which soil seems to be in the best physical condition—i. e., loose and friable? Which contains the most humus? How was this humus provided? If you had a farm of this kind of soil which manure would you use?

HELPS FOR TEACHERS.

Teachers will find additional suggestions for school exercises and problems in agriculture in nearly every elementary text-book on the subject. In addition to these, the following books and pamphlets are devoted entirely to such exercises and problems:

Rural School Agriculture, by W. M. Hays and others, St. Paul, Minn.

Rural School Agriculture, by C. W. Davis, New York, 1907.

One Hundred Experiments in Elementary Agriculture for California Schools, by R. O. Johnson, San Francisco, 1908.

One Hundred Lessons in Agriculture, by A. W. Nolan, Morgantown, W. Va., 1909.

Farm Arithmetic, by Miss Jessie Field, Shenandoah, Iowa, 1909.

Outlines of Agriculture for Rural Schools, by C. M. Evans, Chicago, 1910.

Teachers will do well to purchase through their local dealers copies of as many as possible of these books to be used for reference purposes. Almost any local stationer or book dealer will be able to procure them. In addition to these there are many free publications that will be helpful to both teachers and pupils.

The free publications of the United States Department of Agriculture can be selected from lists which can be procured from Members of Congress or from the Secretary of Agriculture. One of these lists has been prepared especially for teachers and is entitled "Free Publications of the Department of Agriculture Classified for the Use of Teachers." (O. E. S. Cir. 94.)

The publications of the several state institutions are in most cases free to teachers residing in the State, but are not available for others. Every state experiment station issues free agricultural bulletins, and in addition to these the following state institutions have issued pamphlets containing lessons or exercises for public schools:

Alabama—Tuskegee Institute; Connecticut—State Board of Education, Hartford; Georgia—Education Department (Ann. Rpt. 1904), Atlanta; Indiana—Purdue University bulletins, Lafayette; Kansas—State Agricultural College (Industrialist), Manhattan; Massachusetts—Agricultural College, Department of Agricultural Education, Amherst; Michigan—Agricultural College, East Lansing, and State Department of Public Instruction, Lansing; Minnesota—College of Agriculture, University Farm, St. Paul; Missouri—University of Missouri bulletins, and State Board of Agriculture bulletins, Columbia; Nebraska—College of Agriculture, and State Department of Education, Lincoln; New Hampshire—College of Agriculture and Mechanic Arts, Durham; New York—State College of Agriculture (Rural School Leaflets), Ithaca, and State Education Department, Albany; Ohio—College of Agriculture (Extension Bulletins), Columbus; Oklahoma—Agricultural and Mechanical College, Stillwater; Rhode Island—State College (Nature Guard), Kingston; South Dakota—State College of Agriculture and Mechanic Arts, Brookings.